

Original Research Article

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Effect of Zinc with Special Reference to Nano Zinc Carrier on Yield, Nutrient Content and Uptake by Rice (*Oryza sativa* L.)

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ABSTRACT

Keywords

Nano zinc, Bio zinc, Rice, Soil application, Foliar application.

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A field experiment was conducted during *kharif*, 2015 at college farm, college of agriculture, Rajendranagar, Hyderabad to study the effect of various sources of zinc on yield, nutrient content and uptake by rice. The experiment was laid out in Randomized Block Design with 12 treatments and 3 replications. The results of the experiment revealed that the grain (5355 kg ha^{-1}), straw yield (6347 kg ha^{-1}) was recorded highest in the treatment receiving RDF+ Soil application of bio zinc @ 30 kg ha^{-1} at harvest. The highest uptake of N, K, Zn was seen with the application of bio zinc @ 30 kg ha^{-1} , phosphorus uptake was seen highest in RDF@120:60:40 kg ha^{-1} . The results have revealed that the application of bio zinc and nano zinc fertilizers both as soil and foliar application have resulted in obtaining the yields and nutrient uptake and are on par with the conventional ZnSO_4 application.

Introduction

Rice (*Oryza sativa* L.) is the dominant staple food for more than 50% of world population and India ranks first in the world in terms of area of rice cultivation with 44.6 m ha and second in productivity of 2.96 t ha^{-1} . In Telangana state, rice is grown in an area of 17 lakh ha^{-1} with a production of 64 lakh metric tons with a productivity of 3.6 t ha^{-1} (India Stat., 2015-2016). In India, zinc is considered as the fourth important yield limiting nutrient after nitrogen, phosphorus and potassium respectively. The critical limit of available zinc in the soil suitable for rice growth is 0.3 mg kg^{-1} . The plant available zinc in Indian soils extracted with DTPA is less than 1% of total zinc (Takkar and Mann, 1975). It has been postulated that the zinc

deficiency is likely to increase from 49-63% by the year 2025 as most of the marginal soils brought under cultivation are showing the symptoms of zinc deficiency. Hence, application of zinc fertilizers is essential in keeping sufficient amount of available zinc in soil solution, maintaining adequate zinc transport to seeds and for increases in the crop yield. Foliar or combined soil+foliar application of fertilizers under field conditions have proved to be highly effective and can be a practical way to maximize the zinc accumulation and uptake in grains. The efficiency of applied ZnSO_4 is only 1 to 4% and most of the applied zinc is rendered unavailable to plants due to many factors such as leaching, fixation (Nair *et al.*, 2010).

Hence it is essential to minimize the nutrient losses in fertilizer application, increase the crop yield through the exploitation of new applications with the help of nano technology and nano materials. Nano fertilizers have unique physicochemical properties and the potential to boost the plant metabolism (Giraldo *et al.*, 2014). The nano fertilizers or nano encapsulated nutrients might have the properties that are effective to crops, release the nutrients on demand, controlled release of chemical fertilizers that regulate the plant growth and enhanced target activity (DeRosa *et al.*, 2010). Literally very little information exist on the application of nano zinc both in chemical and bioforms applied to soil and foliar application of these materials on rice crop under field conditions. Realizing the importance of zinc in plant growth and at the same time seriousness of its deficiency in soils and plants, the current investigation has been made to study the effect of zinc on yield, nutrient content and uptake by rice.

Materials and Methods

A field experiment was conducted during *khari*, 2015 at College Farm, College of Agriculture, PJTSAU. Experiment was laid out in Randomized Block Design with 12 treatments and 3 replications. The rice variety used was MTU-1010. The treatments were viz., T1-Control (no fertilizers were applied), T2- RDF @ N, P₂O₅, K₂O @ 120:60:40 kg ha⁻¹, T3-RDF+Soil application of ZnSO₄ @ 25kg ha⁻¹ at transplanting, T4 and T5- RDF +Soil application of nano Zn @ 10 kg ha⁻¹ and 15 kg ha⁻¹, T6 and T7- RDF +Soil application of bio Zn @ 15 kg ha⁻¹ and 30 kg ha⁻¹ at transplanting, T8-RDF +foliar application of 0.2 % as ZnSO₄ at tillering and

panicle emergence stage, T9 and T10-RDF +foliar application of 1 ml l⁻¹ and 2 ml l⁻¹ as nano zinc at tillering and panicle emergence stage, T11 and T12 -RDF +foliar application of 1.5ml l⁻¹ and 3ml l⁻¹ as bio zinc at tillering and panicle emergence stage. The study was taken up on a Vertisol (pH 8.24, EC:0.74dSm⁻¹), low in organic carbon (0.42%), low in Nitrogen (242 kg ha⁻¹), high in available Phosphorus (92 kg P₂O₅ ha⁻¹) and high in available Potassium (376 kg K₂O ha⁻¹). The DTPA extractable zinc was 0.3 mgkg⁻¹.

Application of fertilizers

The products *i.e.*, nano zinc and bio zinc formulations were obtained from M/S. Prathishta industries, Alwal, Secunderabad. These are being manufactured by the firm. The nano zinc soil and foliar formulation had Zn content of 40 mg kg⁻¹ and bio zinc soil and foliar formulation contains 3% Zn. Along with 16% organic carbon.

Methodology

The experimental field was ploughed thrice with tractor drawn cultivator followed by puddling with power tiller and later levelled uniformly. The field was divided into plots as per the design by providing bunds for individual plots and irrigation channels to irrigate the plots. Twenty five day old seedlings were transplanted at spacing of 20 × 15 cm with two seedlings per hill. Irrigation was given twice a week and 3-5 cm of standing water was maintained until 2 weeks before harvest. The treatments were evaluated on the basis of yield, nutrient contents. The nutrient uptake was computed using the formula

$$1. \text{ Nutrient uptake (kg ha}^{-1}\text{)} = \frac{\text{Nutrient content (\%)} \times \text{yield (kg ha}^{-1}\text{)}}{100}$$

$$2. \text{ Zinc Nutrient uptake (g ha}^{-1}\text{)} = \frac{\text{Zinc content (mg kg}^{-1}\text{)} \times \text{yield (kg ha}^{-1}\text{)}}{1000}$$

3. Methods employed for determination of the chemical composition of plant samples

Nutrient	Method employed	Reference
N	Micro Kjeldahl (H ₂ SO ₄ : H ₂ O ₂)	Piper, (1966)
P	Spectrophotometer	Piper, (1966)
K	Flame photometer	Piper, (1966)
Zn	Atomic absorption spectrophotometer (AAS)	Lindsay and Norvell (1978)

The recorded data were subjected to statistical analysis using the analysis of variance technique for randomized block design as suggested by Panse and Sukhame (1978).

Results and Discussion

The results obtained from the present investigation on yield, nutrient content and uptake by test crop was discussed in following heads.

Effect of various sources of zinc on yield of rice

The data pertaining to yield is represented in table 1. There is a significant difference seen among the treatments related to grain yield, the treatment receiving RDF+ Soil application of bio zinc @30 kg ha⁻¹ (5355 kg ha⁻¹) recorded the highest grain yield and was on par with RDF +foliar spray of 0.2% ZnSO₄ (5268 kg ha⁻¹), RDF+ Foliar spray of 1ml l⁻¹ as nano zinc (5247 kg ha⁻¹). The lowest grain yield was recorded in the treatment receiving RDF@120:60:40 kg ha⁻¹ (3768 kg ha⁻¹) followed by control (2604 kg ha⁻¹). The highest straw yield was recorded in the treatment receiving RDF+ Soil

application of bio zinc @30 kg ha⁻¹ (6347 kg ha⁻¹) and was on par with RDF +foliar spray of 0.2% ZnSO₄ (6258 kg ha⁻¹), RDF+ foliar spray of 1ml l⁻¹ as nano zinc (6189 kg ha⁻¹). Compared to all the treatments the lowest straw yield was recorded in the treatment receiving RDF@120:60:40 kg ha⁻¹ (4621 kg ha⁻¹) followed by control (3324 kg ha⁻¹). Keram *et al.*, (2012) reported that the higher grain and straw yield with zinc fertilizer application might be due to the fact that zinc plays an important role in biosynthesis of IAA and initiation of primordial for reproductive part which have favored the metabolic reaction within plant.

Essential elements content in grain and straw

The major and micro elements were determined from grain and straw samples of the rice collected at the time of harvest and the results revealed that at harvest the highest N content in grain was seen in the treatment receiving RDF+ Soil application of ZnSO₄@ 25kg ha⁻¹ which was on par with RDF +foliar spray of 0.2% ZnSO₄. In straw the highest N content was seen in the treatment receiving RDF+ Soil application of ZnSO₄ @ 25kg ha⁻¹ which was on par with RDF+ Soil

application of bio zinc @30 kg ha⁻¹. The P content was highest in the treatment receiving RDF@120:60:40 kg ha⁻¹ in both grain and straw. The highest K content in grain and straw was seen in the treatment receiving RDF+ Soil application of bio zinc @30 kg ha⁻¹ which was on par with RDF + foliar spray of 0.2% ZnSO₄. The Zn content in both grain and straw was seen highest in the treatment receiving RDF+ Soil application of bio zinc @30 kg ha⁻¹. An appraisal of data given in table 1 showed that the different treatments of zinc significantly increased nitrogen content in grain as compared to that of straw. The higher nitrogen content in grain could be due to zinc application since zinc is essential for synthesis of DNA and RNA and for metabolisms for the production of carbohydrate, lipids and proteins. The phosphorus content in grain and straw was found to decrease with the application of zinc. It might be due to the antagonistic effect of zinc on P absorption. Zinc was found to inhibit the translocation of P from root to top. The K content was found to increase with the application of zinc this might be due to the synergistic interaction between zinc and potassium.

Essential elements uptake by grain and straw

The perusal of the data given in table 2 indicated that at harvest the highest uptake in grain was seen in the treatment receiving RDF +foliar spray of 0.2% ZnSO₄ (67.7 kg ha⁻¹), followed by RDF+ Soil application of bio zinc @30 kg ha⁻¹. In straw the highest uptake of nitrogen was seen in the treatment receiving RDF+ Soil application of bio zinc @30 kg ha⁻¹ (38.6 kg ha⁻¹) which was followed by RDF + foliar spray of 0.2% ZnSO₄ (37.0 kg ha⁻¹), RDF+ Soil application of ZnSO₄ @ 25kg ha⁻¹ (36.4 kg ha⁻¹), RDF+ foliar spray of 1 ml l⁻¹ as nano zinc (35.5 kg ha⁻¹), RDF+ foliar spray of 1.5 ml l⁻¹ as bio

zinc(34.1 kg ha⁻¹). The lowest straw uptake was recorded in control (9.1 kg ha⁻¹), followed by RDF @ 120:60:40 kg ha⁻¹ (15.8 kg ha⁻¹). The highest uptake of phosphorus in grain (21.5 kg ha⁻¹) and straw (5.08 kg ha⁻¹) was recorded in the treatment receiving RDF@120:60:40 kg ha⁻¹.

The highest uptake of potassium in grain (26.0 kg ha⁻¹) and straw (109.7 kg ha⁻¹) was seen in the treatment receiving RDF+ Soil application of bio zinc @30 kg ha⁻¹. The lowest uptake was recorded in control grain (6.5 kg ha⁻¹), straw (59.2 kg ha⁻¹). The highest uptake of zinc in grain was recorded in the treatment receiving RDF+ Soil application of bio zinc @ 30 kg ha⁻¹ (170.4 g ha⁻¹) which was on par with RDF + foliar spray of 0.2% ZnSO₄ (160.1g ha⁻¹), RDF + foliar spray of 1ml l⁻¹ as nano zinc (152.7g ha⁻¹). The lowest was recorded in control (29.3 g ha⁻¹). The highest uptake of zinc in straw was recorded in the treatment receiving RDF+ Soil application of bio zinc @30 kg ha⁻¹(238.8 g ha⁻¹) which was on par with RDF +foliar spray of 0.2% ZnSO₄ (216.3g ha⁻¹). This was followed by RDF +foliar spray of 1ml l⁻¹ as nano zinc (185.0g ha⁻¹). The lowest was recorded in control (63.2 g ha⁻¹).

The results indicated that application of zinc increased the N and K uptake and this could be attributed to the synergistic effect which might be due to increase enzymatic activity by Zn application. Further the commercial method of application of ZnSO₄@25 kg ha⁻¹ and foliar application of 0.2% ZnSO₄ spray might proved to be increasing the yields.

However the results have clearly brought out the fact that application of bio zinc and nano zinc fertilizers both as soil and foliar application have resulted in obtaining the yields and on par with the conventional zinc application.

Table.1 Effect of various sources of zinc on yield, nutrient content in grain and straw of rice

S.No	Treatments	Yield (kg ha ⁻¹)		N content (%)		P content (%)		K content (%)		Zn content (mg kg ⁻¹)	
		Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
T1	Control(no fertilizers were applied)	2604	3324	0.70	0.20	0.26	0.02	0.20	1.00	11.7	15.0
T2	Recommended dose of N:P ₂ O ₅ :K ₂ O @ 120:60:40 Kg ha ⁻¹	3768	4621	1.18	0.34	0.57	0.11	0.38	1.31	17.4	20.5
T3	RDF+ Soil application of ZnSO ₄ @25Kg ha ⁻¹ at transplanting	4807	5855	1.30	0.62	0.28	0.05	0.40	1.40	22.7	29.6
T4	RDF+ Soil application of nano zinc as impregnated granules@10kg ha ⁻¹ at transplanting	3942	4806	0.85	0.54	0.39	0.03	0.36	1.40	18.0	23.4
T5	RDF+ Soil application of nano zinc as impregnated granules@15kg ha ⁻¹ at transplanting	4043	4963	0.97	0.58	0.36	0.03	0.37	1.30	18.8	22.1
T6	RDF+ Soil application of bio zinc @15kg ha ⁻¹ at transplanting	4623	5531	0.97	0.54	0.32	0.03	0.41	1.35	20.8	22.5
T7	RDF+ Soil application of bio zinc @30kg ha ⁻¹ at transplanting	5355	6347	1.21	0.61	0.26	0.05	0.45	1.48	25.3	37.8
T8	RDF+ Foliar spray of 0.2% as ZnSO ₄	5268	6258	1.29	0.59	0.38	0.05	0.42	1.45	23.4	34.2
T9	RDF+ Foliar spray of 1ml l ⁻¹ as nano zinc	5247	6189	1.15	0.57	0.35	0.04	0.40	1.41	23.7	29.6
T10	RDF+ Foliar spray of 2ml l ⁻¹ as nano zinc	4370	5306	0.92	0.42	0.35	0.04	0.39	1.33	20.8	22.0
T11	RDF+Foliar spray of 1.5ml l ⁻¹ as bio zinc	4740	5740	1.09	0.59	0.37	0.03	0.38	1.37	21.0	24.9
T12	RDF+Foliar spray of 3ml l ⁻¹ as bio zinc	4625	5603	1.00	0.55	0.34	0.02	0.35	1.35	20.2	24.4
	SE(m) ±	71.5	70.8	0.021	0.016	0.012	0.007	0.019	0.014	1.39	1.41
	CD (P=0.05)	209.7	207.8	0.06	0.04	0.035	0.020	0.05	0.04	4.12	4.18

Table.2 Effect of various sources of zinc on nutrient uptake in grain and straw of rice

S.No	Treatments	N uptake		P uptake		K uptake		Zn uptake (g ha ⁻¹)	
		Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
T1	Control(no fertilizers were applied)	29.9	9.1	13.24	1.25	6.5	59.2	29.3	63.2
T2	Recommended dose of N:P ₂ O ₅ :K ₂ O @120:60:40 Kg ha ⁻¹	38.6	15.8	21.55	5.08	14.4	63.7	64.8	90.6
T3	RDF+ Soil application of ZnSO ₄ @25Kg ha ⁻¹ at transplanting	62.6	36.4	14.00	1.60	18.5	86.4	107.5	169.1
T4	RDF+ Soil application of nano zinc as impregnated granules@10kg ha ⁻¹ at transplanting	33.5	26.0	15.54	1.85	14.4	76.9	68.2	102.2
T5	RDF+ Soil application of nano zinc as impregnated granules@15kg ha ⁻¹ at transplanting	39.1	28.8	14.72	1.65	16.4	79.8	79.0	111.9
T6	RDF+ Soil application of bio zinc @15kg ha ⁻¹ at transplanting	44.8	30.0	14.89	1.75	17.3	80.6	88.3	124.8
T7	RDF+ Soil application of bio zinc @30kg ha ⁻¹ at transplanting	64.6	38.6	13.81	1.67	26.0	109.7	170.4	238.8
T8	RDF+ Foliar spray of 0.2% as ZnSO ₄	67.7	37.0	18.83	2.31	22.3	101.9	160.1	216.3
T9	RDF+ Foliar spray of 1ml l ⁻¹ as nano zinc	60.5	35.5	18.31	2.20	20.8	92.7	152.7	185.0
T10	RDF+ Foliar spray of 2ml l ⁻¹ as nano zinc	40.2	22.1	16.70	1.49	16.9	78.4	76.4	116.5
T11	RDF+Foliar spray of 1.5ml l ⁻¹ as bio zinc	51.7	34.1	17.69	1.45	18.0	84.0	95.3	143.0
T12	RDF+Foliar spray of 3ml l ⁻¹ as bio zinc	46.3	30.7	15.80	1.30	17.5	80.7	91.1	135.7
	SE(m) ±	2.0	1.9	0.68	0.30	1.0	1.4	7.2	10.7
	CD (P=0.05)	6.1	5.8	2.03	1.00	3.1	4.4	21.5	31.6

One of the reasons that could be attributed in bio zinc which is encapsulated in the organic compounds *i.e.*, either gluconates or lactates might have prevented the leaching losses of the zinc and made it available to the growth of the crop at the time of its requirement by the crop (Das, 2005), further the use of microorganism and organic matter (16%) which might have contributed to increased microbial activity in the soil by being a source of organic carbon. In addition, use of bio zinc might contribute to the increased organic carbon status of soil in long run. The foliar application of nano zinc was found to be on par with the soil application of bio zinc and the quantity of zinc applied in the form of nano zinc material is much less and hence is easily accessible for uptake by foliage. The results are in submission with Keram (2012),

Fageria (2004) and (Morshedi and Farahbeksha, 2010).

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