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EFFECT OF VARIOUS SOURCES OF ZINC ON GROWTH AND YIELD PARAMETERS, ZINC CONTENT, ZINC UPTAKE BY RICE (*Oryza sativa. L*)

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ABSTRACT

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 nutrition on growth, yield parameters, zinc content and zinc 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 plant height (100.6cm), number of panicles m^{-2} (446.6), number of filled grains $panicle^{-1}$(133.3) have recorded highest in the treatment receiving RDF+ Soil application of bio zinc @30 kg ha^{-1}.The zinc content in grain and straw was also positively influenced by zinc levels. Maximum grain (5355 kg ha^{-1}), straw yield (6347 kg ha^{-1})and zinc uptake in straw (238.8 g ha^{-1}) and grain (170.4 g ha^{-1}) was recorded highest in the treatment receiving RDF+ Soil application of bio zinc @30 kg ha^{-1} at harvest. 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 $ZnSO_4$ application.

KEY WORDS
Nano zinc
Bio zinc
Rice
Yield, Transplanted, Foliar application

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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.com, 2015-2016).

In India 50% of the soils are zinc deficient. The universal deficiency of nitrogen and phosphorus is followed by Zn deficiency (Keram *et al.,* 2014). Zinc deficient soils lead to severe losses in yield and nutritional value. Zinc application in rice increases crop productivity and nutritional value. Zinc increases grain yield in the range of 20 - 50%. Zinc required in small amount, Zn is essential for carbon dioxide evolution and utilization of carbohydrate and phosphorus metabolism and synthesis of RNA (Jyoti Sharma *et al.,* 2013).

Over the years traditional rice varieties were replaced by modern high yielding varieties. Removals of large quantities of zinc by these varieties continuously without rotation and excessive phosphatic fertilizer use have resulted in depletion of available Zn from the soil.

Increased Zn concentration in rice grain is important, from the point of view of nutrition of humans, since rice is the staple food in developing countries of Asia. Also, increased Zn concentration in rice straw also improves cattle nutrition since rice straw is the major feed for cattle in developing countries (Shivay *et al.,* 2008).

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 has proved to be highly effective and can be a practical way to maximize the zinc accumulation and uptake in grains (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 meterials .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). 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 various sources of zinc on crop growth, yield and uptake of zinc nutrient in rice.

MATERIALS AND METHODS

A field experiment was conducted during *kharif,* 2015 at college farm, college of agriculture, PJTSAU. The 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,P_2O_5,K_2O@120:60:40 kg ha^{-1},T3-RDF+Soil application of $ZnSO_4$@25kgha^{-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 $ZnSO_4$ 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 P_2O_5 ha^{-1}) and high in available potassium(376 kg K_2O ha^{-1}).The DTPA extractable zinc was 0.3 mgkg^{-1}.

RESULTS AND DISCUSSION

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.

Bio zinc formulations

The products of bioformulations were obtained by treating the insoluble ZnO with substances like gluconates and lactates and mixed with vegetable protein of maize in water. This process is allowed to undergo hydrolysis, after the hydrolysis the suspension is filtered and the mixture was again enriched with lactates and gluconates and mixed with zinc solubulizing bacteria. For obtaining the solid formulation of bio zinc the required quantity of liquid formulation is mixed with the inert carrier material like bentonite ,talc etc and the formulation is recommended at the rate of 15 kg ha^{-1}.

Nano zinc formulations

Nano zinc formulations are of very recent origin wherein the nano zinc particle are obtained by microbial synthesis using *Rhizoctonia bataticola* in the artificial medium TFR-6PD. The mycelia mat is cultured and released into double distilled water and mixed with ZnO suspension. This broth medium with zinc suspension was induced with *Bacillus subtilis* and is centrifuged. The product obtained is used as it is as liquid formulation.For production of nano zinc granules the liquid formulation obtained by the above method is impregnated on the surface of carrier material like bentonite, talc etc and sold as nano zinc impregnated granules.

Growth and yield parameters

The plant height (cm),Number of tillers and panicles m^{-2}, Number of filled grains $panicle^{-1}$,1000 grain weight (g) were

Table 1: Effect of various sources of zinc on growth and yield components in rice

S.No	Treatment	No of tillers m^{-2}	No of panicles m^{-2}	Filled grain $panicle^{-1}$	Test weight	Yield (kg ha^{-1})	
						Grain	Straw
T1	Control (no fertilizers were applied)	338.8	348.8	84.0	17.0	2604	3324
T2	Recommended dose of N:P_20_5:K_2O @120:60:40 kg ha^{-1}	341.0	365.5	94.0	20.0	3768	4621
T3	RDF +Soil application of $ZnSO_4$ @25kg ha^{-1} at transplanting	398.3	434.5	116.9	21.3	4807	5855
T4	RDF +Soil application of nano zinc as impregnated granules @10kg ha^{-1} at transplanting	363.0	370.6	97.6	20.2	3942	4806
T5	RDF +Soil application of nano zinc as impregnated granules @15kg ha^{-1} at transplanting	356.4	376.9	94.3	20.3	4043	4963
T6	RDF +Soil application of bio zinc@15 kg ha^{-1} at transplanting	374.0	400.4	109.0	20.6	4623	5531
T7	RDF +Soil application of bio zinc @30 kg ha^{-1} at transplanting.	440.0	446.6	133.3	21.8	5355	6347
T8	RDF +foliar spray of 0.2% as $ZnSO_4$	433.4	444.0	123.6	21.7	5268	6258
T9	RDF +foliar spray of 1ml l^{-1} as nano zinc	426.8	442.1	121.3	21.5	5247	6189
T10	RDF +foliar spray of 2ml l^{-1} as nano zinc	365.0	389.9	106.0	20.3	4370	5306
T11	RDF +foliar spray of 1.5ml l^{-1} as bio zinc	392.6	411.7	114.6	21.1	4740	5740
T12	RDF +foliar spray of 3ml l^{-1} as bio zinc	383.8	405.9	109.3	20.9	4625	5603
	SE(m) ±	5.7	11.6	2.3	0.4	71.5	70.8
	CD (P=0.05)	17.0	34.5	7.0	NS	209.7	207.8

Table 2: Effect of various sources of zinc on plant height (cm), zinc content and uptake in grain and straw

S.No	Treatments	Plant height (cm)				Zn content (mg kg^{-1})		Zn uptake (g ha^{-1})	
		30DAT	60DAT	90DAT	Harvest	Grain	Straw	Grain	Straw
T1	Control(no fertilizers were applied)	30.0	76.0	85.9	91.1	11.7	15.0	29.3	63.2
T2	Recommended dose of N:P_20_5:K_2O @120:60:40 kg ha^{-1}	35.5	87.3	90.0	95.6	17.4	20.5	64.8	90.6
T3	RDF+Soil application of $ZnSO_4$ @25kg ha^{-1} at transplanting	39.0	92.0	96.0	97.6	22.7	29.6	107.5	169.1
T4	RDF+Soil application of nano zinc as impregnated granules@10kg ha^{-1} at transplanting	35.8	88.6	93.2	95.9	18.0	23.4	68.2	102.2
T5	RDF+Soil application of nano zinc as impregnated granules@15kg ha^{-1} at transplanting	36.1	89.4	93.7	96.0	18.8	22.1	79.0	111.9
T6	RDF+Soil application of bio zinc @15kg ha^{-1} at transplanting	37.0	90.2	94.7	96.3	20.8	22.5	96.3	124.8
T7	RDF+Soil application of bio zinc @30kg ha^{-1} at transplanting	40.6	93.8	98.9	100.6	32.3	37.8	170.4	238.8
T8	RDF+foliar spray of 0.2% as $ZnSO_4$	40.1	93.2	97.9	100.3	30.4	34.2	160.1	216.3
T9	RDF+foliar spray of 1ml l^{-1}as nano zinc	39.8	92.9	96.8	98.6	29.7	30.1	152.7	185.0
T10	RDF+foliar spray of 2ml l^{-1} as nano zinc	36.8	89.6	94.0	96.0	18.8	22.0	76.4	116.5
T11	RDF+foliar spray of 1.5ml l^{-1}as bio zinc	38.3	91.4	95.8	97.5	21.0	25.1	99.3	143.0
T12	RDF+foliar spray of 3ml l^{-1}as bio zinc	37.8	90.4	95.0	97.3	20.2	24.4	93.1	135.7
	SE(m) ±	0.7	0.91	1.21	1.34	1.39	1.41	7.2	10.7
	CD (P=0.05)	2.1	2.6	3.7	3.9	4.12	4.18	21.5	31.6

recorded by tagging 5 plants in each treatmental plot and the average data was taken.

Grain and straw yield

Grain and straw yields was recorded (kg plot^{-1}) separately for each treatmental plot. Grain yield was recorded at 14 per cent moisture level. The straw was sun dried properly and the yield was recorded at about 14% moisture level.

Estimation of Zinc in plants

Di-acid digestion was carried out using a mixture of HNO_3:$HClO_4$. One gram of powdered oven dried plant material was taken in 100 mL conical flask and 10 ml of di-acid mixture was added to this flask and mixed by swirling. The flask was placed on hot plate in a digestion chamber. The contents were further evaporated until the volume was reduced to 3 to 5 ml but not to dryness. The completion of digestion was confirmed when the liquid become colorless. After cooling the flask, 20 mL of glass double distilled water was added. The volume was made up to 100 ml with glass double distilled water and filtered the solution using what man No. 41 filter paper. The filtrate was used for estimating zinc by AAS.Vogel (1978).

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

Statistical analysis

The data on the observations made were analyzed statistically by applying the technique of randomized block design taken from Panse and Sukhatme (1978). Critical difference for examining significance was calculated at 5 percent level of probability.

Experimental Findings and Discussion

The results obtained on the effect of various sources of zinc on growth and yield parameters, zinc content and zinc uptake by rice is discussed in following heads.

Growth and yield parameters

It can be reported that with the application of zinc the plant height increased with the increasing age of the crop. There was a significant difference and the highest plant height at harvest(Table2)was recorded in the treatment receiving RDF+ Soil application of bio Zn @30 kg ha^{-1} (100.6cm) which was followed by RDF +foliar application of 0.2 % as $ZnSO_4$ (100.3cm) and treatment RDF+ Foliar spray of 1ml l^{-1} as nano zinc (98.6cm).At all the stages the lowest was recorded in control treatment .The results showed that application of various sources of zinc fertilizers significantly influenced and increased the plant height over either absolute control or RDF. This could be attributed to adequate supply of zinc which accelerates the activity of enzyme and auxin metabolism in plants Khan *et al.* (2007).Further it can be observed that the treatment receiving either nano zinc or bio zinc application resulted in production of taller plants. These treatments were able to supply zinc at the time of its requirement. Under submerged soil conditions, Zn fertilization done through Zn loaded nano fertilizer and $ZnSO_4$ had increased growth parameters such as plant height. It was mainly due to nano based Zn fertilizer release Zn slowly during the critical stages of crop growth thereby improving the growth parameters of rice (Yuvaraj and Subramanian, 2014).

The highest number of tillers m^{-2}(Table1) was observed in the treatment receiving RDF+ soil application of bio zinc @30 kg ha^{-1} (440.0 tillers m^{-2}),RDF +foliar spray of 0.2% $ZnSO_4$ (433.4 tillers m^{-2}), RDF+ foliar spray of 1ml l^{-1} as nano zinc (426.8 tillers m^{-2}) and were on par with each other. The lowest was recorded in control (338.8 tillers m^{-2}).Application of zinc significantly increased the tillering and this could be attributed to the improved enzymatic activity and auxin metabolism in plants ,also due to the fact that zinc had a positive effect on formation of stamens and pollen which increased the activity of stamen and there by the flower will fertile well(Banks,2004).In this case also application of nano fertilizers containing zinc as bio zinc application proved to be better as compared to conventional zinc as $ZnSO_4$ presumably due to the timely availability of zinc during critical growth period.

The results indicated that all the applied doses of zinc fertilizers increased significantly the number of panicles m^{-2}(Table1) as compared to absolute control or RDF. The maximum number of panicles was recorded in the treatment receiving RDF+ Soil application of bio zinc@30kg ha $^{-1}$ (446.6 panicles m^{-2}), which was on par with RDF +foliar spray of 0.2% $ZnSO_4$ (444.0 panicles m^{-2}), RDF+ foliar spray of 1ml l^{-1} as nano zinc(442.1 panicles m^{-2}),RDF+ Soil application of $ZnSO_4$@25kg ha^{-1}(434.5 panicles m^{-2}).

The number of filled grains panicle^{-1}(Table1) were increased with the application of zinc treatment and the highest number of filled gains panicle^{-1} was recorded in the treatment receiving RDF+ Soil application of bio zinc @30 kg ha^{-1}(133.3 filled grain panicle^{-1}). Nawaz *et al.*(2004) reported that the increase in number of filled grain panicle^{-1} could attributed to adequate supply of zinc and its effect on enhancing the physiological function of the crop influencing the uptake of plant nutrients through enzymatic activity in the metabolic process and better assimilation of carbondioxide in the panicle.

The data on the 1000 grain weight in rice as influenced by the treatments indicated non significant difference between the treatments. However an increasing grain weight was recorded with the application of zinc. A slight increase in 1000 grain weight could be due to efficient participation of zinc in the number of metabolic processes involved in the production of healthy seed. Similar results were also reported by Abid *et al.*(2011).

There was 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% $ZnSO_4$ (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}).

There was a significant difference seen among different zinc treatments for their effect on straw yield. The treatment receiving RDF+ Soil application of bio zinc @30 kg ha^{-1}(6347 kg ha^{-1}) recorded the highest straw yield and was on par with RDF +foliar spray of 0.2% $ZnSO_4$ (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}).

These findings are in agreement with the results obtained by Keram *et al*.(2012),Suvarna *et al*.(2015),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.

Zinc content and uptake in grain and straw

An appraisal of data given in (Table 2) showed that 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}.At harvest 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% $ZnSO_4$ (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% $ZnSO_4$ (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}).Zinc application increased the % zinc uptake and it was found to be 61.9 to 82.2 in grain, 62.0 to 73.5 in straw.

These results were in accordance with (Phattarakul *et al.,* 2012) and Shivay *et al*.(2008).The increase in zinc uptake in grain and straw at harvest might be due to the presence of increased amount of zinc in soil solution by the application of zinc that might have facilitated the absorption of zinc through phloem. The increase concentration of zinc due to foliar application might be due to zinc absorption by leaf epidermis and remobilization in to the rice grain through phloem and several membranes of zinc regulated transporters which might have regulated this process. 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 zinc uptake and on par with the conventional zinc application. 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.

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