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Effect of Zinc Application on Zn Content and Uptake in Grain, Husk and Straw of Hybrid Rice (*Oryza sativa* L.)

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aim: To assess the Zn content and uptake in grain, husk and straw of rice plant at maturity with and without Zn application under low land soils for hybrid rice (*Oryza sativa* L.).
Study and Design: The experiment was laid down in randomized block design (RBD) with three replications of each treatment.
Place and Duration of Study: The field experiments were conducted at farmer's fields in three districts (*i.e.*, Ranchi, Khunti and Lohardaga) of Jharkhand during *Kharif* season of the year 2015.
Methodology: The experiment was consisted of four levels of zinc (0.0, 2.5, 5.0, 7.5 kg ha^{-1}) applications. After harvesting the grain and straw were collected separately. Brown rice (de-husked rice) was separated by hand mill and the plant materials were processed with following standard procedure of washing, drying and grinding. Zn content in grain (brown rice/de-husked rice), husk and straw of rice plants were analyzed by digestion with tri acid mixture (HNO_3: $HClO_4$: H_2SO_4 in 10:4:1) and concentrations were read with the help of atomic absorption spectrophotometer (ECIL4139).

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Results: Results indicated that the zinc contents and uptake in rice plant at maturity, significantly was influenced by various levels of zinc application. The higher concentration of Zn in grain, husk and straw was showed at 7.5 kg Zn ha^{-1} followed by 5.0 kg Zn ha^{-1} application. The magnitude of Zn concentration was found in an order; straw (88.32-124.77 mg kg^{-1})>grain (23.20-34.27 mg kg^{-1}) >husk (20.37-30.80 mg kg^{-1}).

Conclusion: It was observed that the zinc concentration and uptake was significantly influenced by various levels of zinc applications as compared to no zinc application. The magnitude of Zn concentration was found in an order; straw>grain>husk and it is concluded that the application of Zn in staple foods like rice may play a vital role in reducing Zn deficiency in humans and animals beings.

Keywords: Zinc application; Zn content and uptake in grain; husk and straw; rice (Oryza sativa L.).

1. INTRODUCTION

Food Zn content is very important for human health as the artificial supplementation of foods with essential minerals is often difficult to achieve, particularly in developing countries. Zinc deficiency continues to be one of the key factors in determining rice production in several parts of the country [1]. Rice is the staple food for more than half of the world population and it provides 21% and 15% per capita of dietary energy and protein, respectively [2]. Widespread and extensive zinc deficiency has been reported in lowland rice soils of India, Bangladesh, Pakistan, Philippines, Burma, Indonesia, Japan, Korea, Taiwan and Thailand [3] and Brazil [4]. Therefore, it has been suggested that the application of Zn in staple foods like rice may play a role in reducing Zn deficiency [5,6,7]. Zinc deficiency in plant is noticed when the supply of zinc to the plant is inadequate. Among the many factors which influence zinc supply to the plants, pH, concentration of zinc, iron, manganese and phosphorus in soil solution are very important. Brar and Sekon [8] stated that decrease in availability of zinc in submerged soils are due to the formation of insoluble franklinite ($ZnFe_2O_4$) compound (submerged soil), insoluble ZnS (intense reduced condition), insoluble $ZnCO_3$ (partial pressure of CO_2 coupled with decomposition of OM) and insoluble Zn $(OH)_2$ (alkaline pH). The overall aim of the study is to understand the effect of variable Zn concentrations on Zn accumulation and uptake into grain, husk and straw of hybrid rice *(Oryza sativa L.)* under low land soils of Jharkhand.

2. MATERIALS AND METHODS

The field experiments were conducted at farmers fields in three districts (*i.e.*, Ranchi, Khunti and Lohardaga) of Jharkhand during *Kharif* season of the year 2015 under the TSP programme of "All India Coordinated Research Project on Micro and Secondary Nutrients and Pollutant Elements in Soils and Plants (ICAR)", Ranchi Centre. All the recommended for cultivation practice were adopted under supervision of scientist. The initial soil samples were collected at 0.0 – 15.0 cm depth from the experimental sites. Soil samples were air-dried, ground in wooden pestle and mortar. These ground soil samples were passed through 2.0 mm sieve and stored in properly labeled plastic bags for analysis. Processed soil samples were analyzed for pH, electrical conductivity (EC) by employing the method (1: 2.5:: soil: water) as outline by Jackson [9], organic carbon (potassium dichromate and sulfuric acid method) by Walkley and Black [10]. The DTPA-extractable Zn, Cu, Fe and Mn, were extracted with di-ethelene tri-amine penta-acetic acid (DTPA) solution (pH 7.3) [11]. Hot water soluble boron of soils was estimated as per method outlined by Gupta [12] using Azomethine-H through UV-spectrophotometer at 420 nm. The results of some selected soil physicochemical properties are presented in Table 1.

The experiment was laid down in randomized block design (RBD) and the respective treatments were applied to each plot. All the plots of the experiment received recommended applications of NPK fertilizers (120:60:40 kg ha^{-1}). A basal dose of P and K was applied (60 and40 kg ha^{-1}) one day before transplanting and N was applied at 120 kg ha^{-1} in three split doses *i.e.*, 60 kg N ha^{-1} at basal, 30 kg N ha^{-1} at tillering stage and 30 kg N ha^{-1} at panicle initiation stage of rice plant. The N, P and K were applied through urea, di-ammonium phosphate and potassium chloride (muriate of potash), respectively. Four different levels of zinc *i.e.*, 0.0, 2.5, 5.0, 7.5 kg ha^{-1} were applied using zinc sulfate ($ZnSO_4.7H_2O$). After execution of all the treatment materials in the appropriate plots, 25

Table 1. Physicochemical properties of soil of experimental fields

Characteristics	Average data		
	Ranchi	**Khunti**	**Lohardaga**
Soil type	**sandy loam**	**clay loam**	**clay loam**
pH	5.05	5.47	5.50
EC (dS m^{-1})	0.07	0.10	0.09
OC (g kg^{-1})	4.21	5.18	4.64
Fe (mg kg^{-1})	57.04	57.92	63.79
Mn (mg kg^{-1})	30.21	52.92	39.86
Zn (mg kg^{-1})	0.35	0.43	0.49
Cu (mg kg^{-1})	0.89	1.34	1.40
B (mg kg^{-1})	0.46	0.51	0.71

days old rice seedlings were transplanted with plant to plant and row to row distance of 15 cm and 20 cm, respectively in 10 × 10 m^2 plot size. Required agronomic management practices were followed as per recommended package. Then the rice seedlings were allowed to grow till the harvest. After harvesting the grain and straw were collected separately. Brown rice (de-husked rice) was separated by hand mill and the plant materials were processed with following standard procedure of washing, drying and grinding. Ground material (0.5 g) was digested with 10 mL of tri-acid mixture (HNO_3: $HClO_4$: H_2SO_4 in 10:4:1). It was kept in digestion chamber till complete digestion [13]. The residue was dissolved in double-distilled water and after filtration (Whatman filter paper No. 42) final volume was made to 50 mL. The Zn content in grain (brown rice/de-husked rice), husk and straw of rice and DTPA-$CaCl_2$ extractant of soil were determined with the help of atomic absorption spectrophotometer (ECIL4139). The Zn uptake was calculated by the percent Zn content of plant parts was multiplied by the respective yield. Agronomic zinc use efficiency (AZUE) was calculated using the following formula [14].

$$\text{AZUE (\%)} = [(A-B)/C] \times 100$$

Where,

A= Zn uptake in treatment plot
B= Zn uptake in control plot
C= Quantity of Zn applied in plot

Field experiment data were analyzed statistically using analysis of variance (ANOVA) (Microsoft Excel 2007).

3. RESULTS AND DISCUSSION

The zinc concentration and uptake in rice plant at maturity was influenced by various levels of zinc applied to soil (Tables 2; 3; 4). Since, the grain zinc accumulation mechanisms in rice plant can be grouped into two categories according to the predominant sources of Zn loading: as continued root uptake during the grain filling stage [15] and remobilization of Zn from shoots or roots [16]. While in this study, the Zn concentration and uptake in grain ranged from 23.20 to 34.27 mg kg^{-1} and 71.40 to 127.72 g ha^{-1}, respectively due to successive increment in zinc addition to soil (Table 2). The zinc concentration and uptake showed highest with 7.5 kg Zn ha^{-1} application. The increase in the zinc content in grain might be due to the presence of increased amount of Zn in soil solution by the application of zinc that facilitated greater absorption. Increase in Zn content in grain due to zinc fertilization was reported earlier [4,17,18,19].

In case of husk of rice, significantly highest zinc concentration was found 30.80 mg kg^{-1} at the rate of Zn application 7.5 kg ha^{-1}, which was statistically at par to concentration 27.36 mg kg^{-1} at 5.0 kg Zn ha^{-1} application and that was about 51.20% and 34.36% greater concentration over the control (no Zn application), respectively (Table 3). Muthukumararaja and Sriramachandrasekharan [20] also reported that the increase in zinc concentration in rice husk with zinc applications. While, zinc uptake in rice husk, the highest uptake was showed with 7.5 kg Zn ha^{-1} followed by 5.0 and 2.5 kg Zn ha^{-1} applications, respectively.

Regarding straw (Table 4), Zn concentration was found 88.32 mg kg^{-1} in control and higher 124.77 mg kg^{-1} at the Zn application level at 7.5 kg ha^{-1}. All three levels of Zn applications *i.e.*, 2.5, 5.0 and 7.5 kg ha^{-1} were found significantly superior than the control. The Zn concentration in straw gradually increases with the application of increasing doses. Similar result was also reported by Naik and Das [21] and Kulhare et al. [19]. Moreover, Fageria et al. [22] and Fageria and Bailgar [23] also reported much lower Zn concentration in grain of upland rice than in straw. The magnitude of Zn concentration was found in an order; straw>grain>husk that results is conformity with the reported by Firdous et al. [24] in rice crop. While, zinc uptake in straw, the highest uptake was observed 1111.32 g ha^{-1} followed by 1029.17 g ha^{-1}, respectively at 7.5 and 5.0 kg Zn ha^{-1} applications (Table 4).

Agronomic zinc use efficiency (AZUE) by rice with soil application of Zn followed the order: straw (6.05 g ha^{-1}) > de-husked rice (0.71 g ha^{-1}) > husk (0.35 g ha^{-1}). Interestingly, Zn recovery was considerably higher with 2.5 kg Zn ha^{-1} application compared to other application (Table 5).

Table 2. Effect of zinc application on Zn content and uptake in grain of rice (Brown rice/de-husked rice) (*Oryza sativa* L.)

Level of zinc	Zn content (mg kg^{-1}) Name of districts			pooled	Zn uptake (g ha^{-1})
	Ranchi	Khunti	Lohardaga		
Control plot	24.5	19.60	25.51	23.20	71.40
2.5 kg Zn/ha	26.0	22.60	29.17	25.92	87.49
5 kg Zn/ha	31.1	24.10	36.26	30.49	108.21
7.5 kg Zn/ha	36.8	26.60	39.42	34.27	127.72
Mean±Std	29.6±5.40	23.20±2.80	32.10±6.49	28.47±6.21	98.71±27.07
CD (p≤0.05)	5.50	1.73	3.04	4.06	14.51
CV (%)	18.3	12.03	19.91	21.80	0.27

Table 3. Effect of zinc application on Zn content and uptake in husk of rice (*Oryza sativa* L.)

Level of zinc	Zn content (mg kg^{-1}) Name of districts			Pooled	Zn uptake (g ha^{-1})
	Ranchi	Khunti	Lohardaga		
Control plot	22.6	17.60	20.92	20.37	31.33
2.5 kg Zn/ha	25.9	19.00	27.17	24.02	40.48
5 kg Zn/ha	30.6	20.30	31.17	27.36	48.47
7.5 kg Zn/ha	33.3	23.10	36.01	30.80	57.35
Mean±Std	28.1±4.60	20.10±2.50	28.82±6.12	25.64±6.02	44.45±12.75
CD (p≤0.05)	3.60	2.01	3.05	4.26	7.67
CV (%)	16.3	12.59	21.25	23.49	0.29

Table 4. Effect of zinc application on Zn content and uptake in straw of rice plant

Level of zinc	Zn content (mg kg^{-1}) Name of districts			pooled	Zn uptake (g ha^{-1})
	Ranchi	Khunti	Lohardaga		
Control plot	84.3	83.40	97.26	88.32	720.91
2.5 kg Zn/ha	96.3	98.40	121.42	105.37	892.75
5 kg Zn/ha	110.8	107.20	136.17	118.06	1029.17
7.5 kg Zn/ha	118.5	110.40	145.42	124.77	1111.32
Mean±Std	99.9±13.0	99.90±11.30	125.07±19.02	109.13± 19.06	938.54±190.35
CD (p≤0.05)	4.7	7.39	5.69	9.72	72.30
CV (%)	13.1	11.31	15.21	17.46	0.20

Table 5. Agronomic zinc use efficiency (AZUE) in De-husked rice, husk and straw of rice plant at maturity

Level of zinc	Zinc use efficiency (%) Plant parts			Pooled
	De-husked rice	Husk	Straw	
Control plot	-	-	-	-
2.5 kg Zn/ha	0.64	0.37	6.87	2.63
5 kg Zn/ha	0.74	0.34	6.17	2.42
7.5 kg Zn/ha	0.75	0.35	5.12	2.07
Mean	0.71	0.35	6.05	2.37

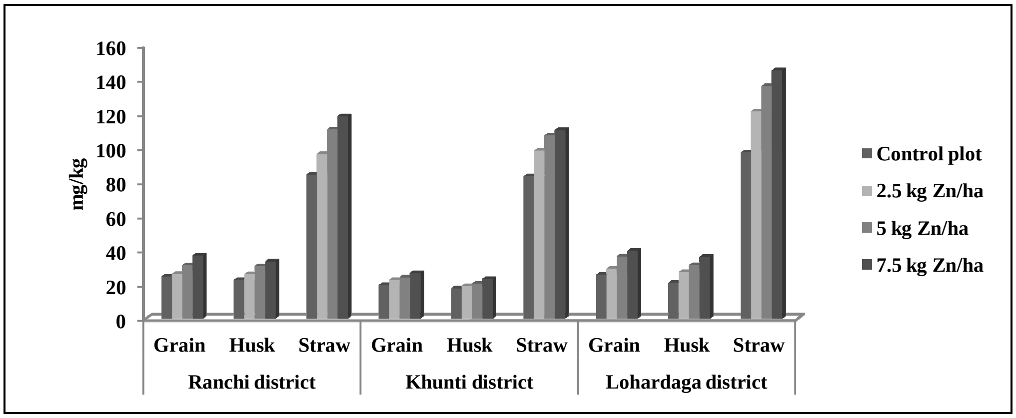

Fig. 1. Accumulation of zinc in rice plant at maturity

The accumulation of Zn in different parts of rice plant at maturity has been depicted in Fig. 1. The maximum amount of Zn was accumulated in straw which was gradually translocated to grain → husk of rice plant parts. Among the rice plant parts the accumulation of Zn in terms of its content was in an order of straw>grain>husk. As far as the effect of different levels of Zn application on Zn translocation/accumulation pattern is concerned the preference of translocation of zinc was higher in all parts where application of dose level 7.5 kg Zn ha^{-1} showing higher extent of it. Since that result was conformity with the reported by Firdous et al. [24] in rice crop. They were reported that, at maturity of rice plant the magnitude of Zn concentration was found in an order; straw>brown rice>husk was recorded. The translocation of zinc was higher in straw than other plants parts at maturity.

4. CONCLUSIONS

It was observed that the zinc concentration and uptake was significantly influenced by various levels of zinc applications as compared to no zinc application. The magnitude of Zn concentration was found in an order; straw>grain>husk. Therefore, it has been suggested that the application of Zn in staple foods like rice may play a role in reducing Zn deficiency in humans and animals beings.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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