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# Agronomic biofortification of zinc in different rice genotypes

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**Abstract**
Zinc deficiency in soils and plants is a global micronutrient deficiency problem reported in many countries. Zinc deficiency can be corrected by enriching the food grains through fertilizer application to the plant in both soil and foliar method. A field experiment on agronomic biofortification with zinc in rice was carried out during thaladi season of 2013-14 and 2014-15 at Tamil Nadu Agricultural University, Coimbatore. The experiment was laid out in split plot design with three replications consisted of two zinc levels (-Zn and +Zn, 100 kg $ZnSO_4$. 7 $H_2O$ $ha^{-1}$ plus foliar spray @0.5%) in main plot and 18 rice genotypes in subplot. Soil and foliar application of zinc significantly increased the grain and straw yield and also the zinc concentration in processed rice grains. Based on the zinc concentration in processed rice the genotype Co43, Improved white ponni, ADT 38 and TRY 1 showed higher response for zinc application.

**Keywords:** Zinc, rice genotypes, biofortification, yield

## Introduction

The world's population is estimated to increase from 6 billion to about 10 billion by 2050. To meet the food demand of the growing world population, a large increase in food production is required. The first Green revolution in India brought a grand success in achieving self-sufficiency in food production but it also caused a greater exploitation of the micronutrient soil reserves. Micronutrient deficiencies drastically affect the growth, metabolism and reproductive phase in plants, animal and human beings. Particularly, zinc deficiency in soils and plants is a global micronutrient deficiency problem reported in many countries and 30% of the world soils are deficient in available zinc (Alloway, 2008) [1]. In India, zinc is now considered the fourth most important yield-limiting nutrient after, nitrogen, phosphorus and potassium, respectively. The critical limit of effective Zn in the soil suitable for rice growth is 1.2 mg $kg^{-1}$ (DTPA extract) (Takkar and Mann, 1975) [2]. The plant available zinc in Indian soils, extracted with DTPA constitutes a very small portion (<1%) of total zinc. Rice (Oryza sativa L.) is the dominant staple food for more than half of the world's population. Worldwide, more than 3.5 billion people depend on rice for more than 20% of their daily calorie intake (Seck *et al.,* 2012) [3].

Malnutrition (improper diet and nutrition) and especially the under nutrition (inadequate nutrition) arises among the poor where food supply and diversification are lacking. People in the developing countries are at great risk, since majority of them are vegetarians and are not able to meet the required zinc due to its deficiency in plants. The possible solutions to correct micronutrient deficiency in humans may be food supplementation, food fortification or biofortification. The former two Programs require infrastructure, purchasing power, access to market and health care centres and uninterrupted funding, which have their own constraints (NAIP-ICAR, 2014) [4]. Biofortification has been defined as the process of increasing the bioavailable concentrations of essential elements in edible portions of crop plants through agronomic intervention or genetic selection. "Agronomic biofortification" through the application of fertilizer (inorganic or organic), modification of cultivation systems, soil management and new irrigation strategies have proved effective in enriching micronutrients content in rice grain by controlling the availability of soil micronutrients for plant. Foliar or combined soil + foliar application of Zn fertilizers under field conditions are highly effective and very practical way to maximize uptake and Zn accumulation in grains (Cakmak, 2008) [5].

With this background, field experiments were conducted to find the high grain zinc content in different genotypes with soil and foliar application of zinc.

## Material and methods

A field experiment was conducted during the two consecutive years 2013-14 and 2014-15 in Thaladi season at two different Zn deficient sites at the wetlands of TNAU farm, Coimbatore. The soil of the experimental site was sandy clay loam in texture and had the following chemical properties: pH - 7.85 (1:2.5 soil water ratio), EC - 0.22 $dSm^{-1}$, Available N- 217 kg $ha^{-1}$, Available P - 29.7 kg $ha^{-1}$, Available K - 324 $kgha^{-1}$, Organic carbon - 0.24 per cent, DTPA Cu -1.42 mg kg $^{-1}$, DTPA Fe- 5.47 mg $kg^{-1}$, DTPA Mn 15.4 mg $kg^{-1}$ and DTPA Zn 1.09 mg $kg^{-1}$, the soil was deficient in available zinc (< 1.22 mg $kg^{-1}$).

The experiment was laid out in a split plot design, replicated which was three times. Main plot treatments were Zn at two levels (-Zn and +Zn, 100 kg $ZnSO_4$. 7 $H_2O$ $ha^{-1}$ at basal and 0.5 per cent ZnSO4.7H2O foliar spray thrice at flowering, milk and dough stages of rice plant) and sub plot treatments were rice genotypes (18 Nos.) with a plant spacing of 20 X 15 cm. The genotypes included in this study were Co43, Co49, Co50, Improved white Ponni, IR 20, $CoRH_4$, Swarna, Bhavani, TPS 3, ADT 38, ADT 39, ADT 46, ADT 49, BPT 5204, TRY I, TRY III, PYR I and DRRH3. Rice seeds were obtained from the different Research stations of Tamil Nadu Agricultural University. Recommended dose of fertilizer @ 150: 50: 50 NPK kg ha-1, in case of varieties, 175: 60:60 NPK kg $ha^{-1}$ for hybrid and 75: 50: 50 NPK kg $ha^{-1}$ for improved white ponni. Full dose of P was applied basally and N and K were applied at four equal splits at basal, active tillering, panicle initiation and fifty percent flowering stages. Zinc was applied at basal in the form of $ZnSO_4$ $7H_2O$ (100 kg $ha^{-1}$) as per treatment plots.

To find the zinc content in processed grains, samples of un-husked (whole grain with husk), brown (whole-grain rice with the inedible outer hull removed.) and white (outer layers of the caryopsis including pericarp, testa, nucella and part of the aleurone layer along with the embryo were removed, by using rubber roll sheller) were used. At maturity, yield of grain and straw was determined by harvesting an area of $5m^2$ in the centre of each plot and the yield data were adjusted to 14% moisture content.

**Table 1:** Details of analytical procedures employed in analysis

| Estimations | Procedure | Reference |
|---|---|---|
| Soil reaction (pH) | 1:2.5 soil water suspension J | Jackson (1973) |
| Electrical conductivity (EC) | 1:2.5 soil water suspension | Jackson (1973) |
| Organic carbon | Chromic acid wet digestion | Walkley and Black (1934) |
| Available nitrogen | Alkaline permanganate method | Subbiah and Asija (1956) |
| Available phosphorus | 0.5 M NaHCO3 (pH-8.5) | Olsen *et al.* (1954) |
| Available potassium | Neutral N NH4OAc | Stanford and English (1949) |
| DTPA micronutrients | DTPA extraction and AAS method | Lindsay and Norvell (1978) |

## Result and discussion

The results obtained from the present investigations as well as relevant discussion based on the data pooled over two consecutive years (2013-2014 and 2014-2015) have been presented under following heads.

## Grain yield and straw yield

Based on the pooled data the grain yield was significantly influenced by the zinc application and genotypes, which ranged from 4553 kg $ha^{-1}$ in control of Bhavani to 7559 kg $ha^{-1}$ in Zn applied plot of $CORH_4$ (Table 2) and it was found that the application of NPK with zinc increased the grain yield considerably than NPK alone in all the genotypes. This finding is in agreement with Nawaz *et al.* (2015) [6]. The genotype $CORH_4$ registered the highest grain yield in both No zinc (6674 kg $ha^{-1}$) and zinc applied (7559 kg $ha^{-1}$) while the lowest grain yield was recorded in Bhavani for both control (4553 kg $ha^{-1}$) and zinc applied treatments (5271 kg $ha^{-1}$). Peda Babu *et al.* (2007) [7] also reported that the yield increase may also be due to enhanced synthesis of carbohydrates and their transport to the site of grain production. The foliar spraying of zinc resulted in better absorption of zinc and in turn helping in the photosynthetic activities and effective translocation to storage organs which might have contributed for increased yield. This was in accordance with the earlier findings of Datta and Dhiman (2001) [8].

**Table 2:** Grain and straw yields of rice genotypes (kg $ha^{-1}$) at harvest

| Cultivars | Grain yield (kg $ha^{-1}$) | | Straw yield (kg $ha^{-1}$) | |
|---|---|---|---|---|
| | M1 | M2 | M1 | M2 |
| Co43 | 4862 | 5777 | 6059 | 7251 |
| Co49 | 5809 | 6682 | 7070 | 8109 |
| Co50 | 5936 | 6736 | 7547 | 8668 |
| I.W.Ponni | 4804 | 5467 | 5979 | 6723 |
| IR 20 | 5106 | 5827 | 6399 | 7182 |
| $CoRH_4$ | 6674 | 7559 | 8564 | 9327 |
| Swarna | 5414 | 6344 | 6794 | 8011 |
| Bhavani | 4553 | 5271 | 5599 | 6602 |
| TPS 3 | 4798 | 5644 | 6149 | 6932 |
| ADT 38 | 6093 | 6922 | 7369 | 8477 |
| ADT 39 | 5088 | 5787 | 6463 | 7076 |
| ADT 46 | 6198 | 7083 | 7756 | 8938 |
| ADT 49 | 5619 | 6534 | 6766 | 8028 |
| BPT 5204 | 5043 | 5931 | 6355 | 7210 |
| TRY I | 5269 | 5939 | 6771 | 7320 |
| TRY III | 5114 | 5982 | 7042 | 7769 |

| | | | | |
|---|---|---|---|---|
| PYR 1 | 5475 | 6327 | 6557 | 7774 |
| DRRH3 | 6142 | 6969 | 7903 | 8729 |
| Mean | 5444 | 6265 | 6841 | 7785 |
| | **SEd** | **CD(0.05)** | **SEd** | **CD(0.05)** |
| M | 47 | 201 | 54 | 231 |
| V | 35 | 69 | 45 | 89 |
| M x V | 67 | 209 | 81 | 244 |
| V x M | 49 | 98 | 63 | 126 |

## Zinc concentration in processed rice grains

The data on zinc concentration for two consecutive years and their pooled data were given in the Table 3. The result and discussion are given based on the pooled data.

### Whole rice grains

The zinc concentration in rice grains was significantly influenced by soil plus foliar zinc application. Zinc concentration in whole rice grains ranged from 14.6 to 37.8 mg $kg^{-1}$. The genotype ADT 38 (37.8 mg $kg^{-1}$) had markedly higher Zn in zinc applied treatment, however it was statistically on par with TRY 1 (37.7 mg $kg^{-1}$) and the lower Zn concentration was noted in BPT 5204 (27.6 mg $kg^{-1}$). In the present investigation, soil plus foliar application of Zn increased the grain zinc concentration by 43% over NPK alone, which was noted by Yerokun and Chirwa (2014) [9] in maize and wheat. The increase in the zinc concentration in grain might be due to the continued Zn uptake by root from soil solution as a major mechanism, as well as Zn absorption and remobilization from leaf and stem tissues to developing grains through phloem as a result of foliar Zn application at latter growth stages. This result was confirmed by the findings of Yuan *et al*. (2013) [10]. There was a difference in grain Zn concentration among the genotypes and this may be due to the difference in loading ability of Zn from the panicle tissues to the grains (Markole *et al*., 2020) [11].

**Table 3:** Zinc concentration in processed rice grains (mg $kg^{-1}$)

| Cultivars | Whole grain | | Brown rice | | Polished rice | |
|---|---|---|---|---|---|---|
| | **M1** | **M2** | **M1** | **M2** | **M1** | **M2** |
| Co43 | 15.6 | 37.2 | 13.0 | 29.2 | 7.4 | 11.4 |
| Co49 | 17.4 | 33.7 | 14.9 | 29.9 | 8.1 | 12.3 |
| Co50 | 19.5 | 28.7 | 17.8 | 26.8 | 8.9 | 11.5 |
| I.W.Ponni | 25.2 | 37.4 | 22.4 | 33.8 | 10.4 | 14.6 |
| IR 20 | 17.1 | 29.6 | 14.6 | 25.3 | 8.1 | 11.7 |
| $CoRH_4$ | 20.9 | 31.4 | 17.5 | 28.7 | 9.8 | 13.8 |
| Swarna | 16.2 | 30.0 | 13.5 | 21.9 | 7.6 | 10.6 |
| Bhavani | 16.1 | 32.1 | 13.4 | 25.1 | 6.5 | 12.1 |
| TPS 3 | 19.7 | 31.2 | 15.5 | 21.2 | 7.1 | 13.8 |
| ADT 38 | 19.0 | 37.8 | 15.4 | 34.0 | 7.7 | 14.8 |
| ADT 39 | 16.2 | 37.5 | 13.9 | 31.6 | 7.5 | 13.6 |
| ADT 46 | 21.3 | 29.4 | 18.9 | 27.2 | 8.9 | 15.0 |
| ADT 49 | 18.3 | 29.5 | 15.0 | 24.6 | 8.0 | 11.7 |
| BPT 5204 | 14.6 | 27.6 | 12.7 | 21.5 | 7.0 | 11.0 |
| TRY I | 22.7 | 37.7 | 19.8 | 32.5 | 10.0 | 15.7 |
| TRY III | 17.1 | 35.4 | 15.2 | 29.5 | 8.0 | 13.1 |
| PYR 1 | 17.2 | 29.0 | 14.6 | 20.6 | 8.3 | 11.0 |
| DRRH3 | 18.5 | 29.2 | 16.3 | 26.7 | 8.9 | 13.3 |
| Mean | 18.5 | 32.4 | 15.8 | 27.2 | 8.2 | 12.8 |
| | SEd | CD (0.05) | SEd | CD (0.05) | SEd | CD (0.05) |
| M | 0.6 | 2.5 | 0.6 | 2.4 | 0.2 | 0.9 |
| V | 0.5 | 1.0 | 0.3 | 0.5 | 0.2 | 0.4 |
| M x V | 0.9 | 2.6 | 0.7 | 2.4 | 0.3 | 1.0 |
| V x M | 0.7 | 1.4 | 0.4 | 0.8 | 0.3 | 0.6 |

### Brown rice

The zinc concentration in brown rice ranged from 12.7 to 34.0 mg $kg^{-1}$ and there was a significant effect in Zn concentration due to zinc application. Genotypes exerted notable difference in Zn concentration, in which Improved white ponni had the highest Zn concentration followed by TRY 1 and the lowest Zn was noted in BPT 5204 and PYR 1. From the result it was found that the zinc concentration in brown rice was lesser than in whole grain, which may be due to the removal of hull which normally contains high micronutrients (Lu *et al*., 2013). The brown rice Zn concentration varied widely among different genotypes both in control as well as in soil plus foliar applied Zn treatments, indicating that some genotypes can efficiently remobilize Zn taken up in the early stage and store in source tissues, even when the plants were grown in Zn-deficient conditions (Saha *et al*., 2013) [13].

### Polished rice

The zinc concentration of polished rice in main plots ranged from 6.5 to 15.7 mg $kg^{-1}$. TRY 1 had higher Zn concentration in adequate zinc applied treatment (15.7 mg $kg^{-1}$) and improved white ponni registered higher zinc concentration in control (10.4 mg $kg^{-1}$); whereas the lower Zn concentration was observed in Bhavani (6.5mg $kg^{-1}$) and Swarna (10.6 mg $kg^{-1}$) in control and zinc treatment plot. Around 75% of total grain Zn was reported to be present in aleurone layer of brown rice, which revealed that Zn is most abundant in aleurone layer and embryo In this study, zinc application increased the Zn concentration in polished rice by 36% over control. This result was in line with Wei *et al*. (2012) [15]. The higher Zn content found in the polished rice in the soil and foliar application of Zn treatment might be due to the movement inwards from the outer grain tissues to the endosperm through the apoplast from the nucellar epidermis which completely encircles the endosperm (Sperotto *et al*., 2010) [14] and also due to enhanced amount of nicotianamine and deoxymugineic acid which play important role in this process. These results were confirmed by Phattarakul *et al*. (2012) [16].

## Conclusion

Application of zinc in soil and foliar application increased the grain zinc concentration in all genotypes. Timing of foliar Zn application is an important factor determining the effectiveness of the foliar applied Zn fertilizers in increasing grain Zn concentration. Foliar application at flowering, milk and dough stages increased grain Zn concentration in processed rice grains.

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