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REVIEW ARTICLE

Effect of zinc on growth, Yield attributes and yield of rice: A Review

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ABSTRACT
Globally, more than two billion people are affected with deficiency of micronutrient alone, in this most of the peoples are from developing countries and poor families, most prevalent nutrients are Zn, Fe, I and Vitamin A. Approximately, every year five million children dies due to micronutrient deficiency. Currently, micronutrient malnutrition is considered to be the most serious threat and global challenge to human kind and it is avoidable. Cereal crops mainly rice which is staple food of around more than half of the population of the world, play an important role in satisfying daily calorie intake in developing world, but they are inherently very low in Zn concentration in grain. It provides 21% of energy and 15% of protein requirements but does not provide essential micronutrient i.e. Zn to eliminate their deficiencies. Scientific evidences show this is technically feasible without compromising agronomic productivity. Biofortification is the process by which the nutritional quality of food crops is improved through agronomic practices, conventional plant breeding, or modern biotechnology. Biofortification differs from conventional fortification aims to increase nutrient levels in crops during plant growth rather than through manual means during processing of the crops.
Key words – *Biofortification, Rice, Zn, agronomic productivity*

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INTRODUCTION

Rice (*Oryza sativa* L) is the staple food of about 65% of the world's population [7] and consumed by more than 75% in Asian countries [1]. In global scenario, it occupied 164.72 million hectare with annual production of 745.70 million tons [7] and widely cultivated cereals and playing critical roles in food and nutritional security especially in South Asia and East Asia. In world, Asia accounts for 90% of the world's production and consumption of rice because of its favorable warm and humid climate [7].

Zinc is a most important micronutrient required for structural and functional integrity of biological membranes and also helps in detoxification of highly aggressive free radicals [4]. Zn plays various roles in basic biochemical processes such as catalysis or activation of enzymes, protein synthesis, carbohydrate and auxin metabolism, chlorophyll production, pollen formation, cytochrome and nucleotide synthesis, maintenance of membrane integrity, and energy dissipation. Zinc (Zn) deficiency is a well-documented global health problem and reliance on cereal based food induce Zn deficiency related health problem, such as impairments in physical growth, immune system and brain function [32]. Zn deficiency is common in India around 10 M ha area is deficient. After nitrogen, zinc is the second most yield-limiting nutrient in rice [25].

EFFECT OF ZINC ON GROWTH

Arif *et al.* [2] found that application of Zn significantly increased the growth characters, chlorophyll contents and yield quality. Zn application increase the rice yield content of Zn was also relatively high in grain, indicating the necessity of Zn application to plants. Gour *et al*. [8] planned an experiment having seven treatments included control, recommended dose of fertilizer (RDF) NPK @ 120:60:60 kg/ha, RDF + S, Zn, B (40:05:1.5 kg/ha), customized fertilizer with composition of N:P:K:Zn:B; 11:32:13:0.9:0.24% @ 312.5 kg/ha, 75% RDF + 25% N through sewage sludge, 75% RDF + 25% N through vermicompost, 75% RDF + 25% N through *Sesbania.* Experiment showed that treatment that have application of 40 kg S, 5 kg Zn and 1.5 kg B per ha along with recommended dose of NPK had higher plant height, more number of tillers, higher 1000-grain weight and higher grain yield of rice. Nawaz *et al.* [22] in an experiment found that, with five treatments including T_1 (Control; no $ZnSO_4$ application), T_2 (application of $ZnSO_4$ alone at 10-15 days after transplanting (DAT), T_3 (application of $ZnSO_4$ + NPK at puddling stage), T_4 (application of $ZnSO_4$ + nitrogenous fertilizer at 20-25 DAT) and T_5 (application of $ZnSO_4$ + NPK at 20-25 DAT), maximum plant height (98.94 cm), and number of tillers was recorded with the treatment where $ZnSO_4$ was applied at puddling stage along with recommended dose of NPK while the control plot showed minimum plant height and number of tillers. Rana and Kashif [27] experiment conducted with ten treatment of zinc (source of zinc, dose, method of application) and recommended dose of NPK. They showed the soil applied Zn-EDTA (10.0 kg/ha) produced highest plant height, tillers per plant (145 tillers) and chlorophyll content. Kumar and Qureshi [15] planned an experiment to compare the transformation, redistribution, availability and relative effectiveness of Zn from different fertilizer sources *viz.* Zn-DTPA (Zinc chelated with di-ethylene tri-amine penta-acitic acid), Zn-EDTA (Zinc chelated with ethylene di-amine tetra-acetic acid), Zn-CH (Zinc chelated with a mixture of DTPA & EDTA) and $ZnSO_4.7H_2O$ (Zinc sulphatehepta hydrate) applied at various zinc levels (5, 10 and 20 mg/kg) to an Inceptisols in a greenhouse experiment. The greenhouse results study expressed that the application of zinc through three sources significantly increased wheat (*Triticum aestivum* L.) and succeeding maize (*Zea mays* L.) dry matter yield and shoot:root compared with the control at increased levels of zinc. Muamba and Ambara [18] in an experiment found that highest plant height 129 cm obtained when 30 kg $ZnSO_4$ per ha was applied. Boonchuay *et al*. [3] reported the Zn application through foliar spray at various growth stages and frequencies had no significant effect on growth attributes *viz*, plant dry weight, plant height, leaf area index and number of tillers. In an experiment reported that dry matter production significantly increased with graded dose of zinc over control. The maximum dry matter production of 2.98 g/pot at tillering and 40.93 g/pot at panicle initiation was obtained with application of 5 mg Zn/kg which was about 44 to 60% greater as compared over control, conducted by Muthukumararaja and Sriramachandrasekharan [20]. Keram *et al*. [12] in an experiment reported that maximum plant height, dry matter, chlorophyll content, leaf area index and number of tillers with application of recommended dose of NPK+20 kg Zn/ha. Mandal *et al*. [17] found that application of 10 kg Zn in three splits gave significantly higher plant height, dry matter accumulation and number of tillers. Shivay *et al.* [30] reported that the Zn enriched-urea (3.5%) recorded significant maximum plant height, leaf area index and dry matter accumulation of aromatic rice. Naik and Das [21] examined the relative performance of Zn-EDTA and $ZnSO_4$. Initial incorporation of Zn-EDTA showed pronounced effect on growth over $ZnSO_4$. The highest growth attributes such as plant height, dry matter and were recorded with application of 1 kg Zn/ha as Zn-EDTA as basal. Khan *et al.* [13] conducted an experiment to evaluate the effect of different levels of zinc *i.e.* 0, 5, 10 and 15 kg/ha along with the basal doses of 120 kg N, 90 kg P_2O_5 and 60 kg K_2O per ha. They reported maximum plant height (74.38 cm) and maximum number of tillers/plant (17.41) with 10 kg Zn/ha, and lowest plant height (59.50 cm) was recorded in control. Correia *et al*. [5] was studying on zinc forms and found that growth parameters were found maximum in Zn-EDTA than $ZnSO_4$ on rice. Kumar *et al*. [14] conducted experiment with four treatments (stubbles + $ZnSO_4$/Zn EDTA, Stubbles + FYM, Stubble + $ZnSO_4$/Zn EDTA + FYM and Stubbles). They reported application of stubbles + $ZnSO_4$/Zn EDTA + FYM recorded significantly higher plant height, plant dry matter and number of tillers over rest of the treatments.

EFFECT OF ZINC ON YIELD ATTRIBUTES AND YIELD

Yin *et al.* [33] experiment was conducted on a low Zn soil to determine the effect of different Zn fertilization strategies on grain Zn concentration and Zn allocation in different plant tissues of rice. Six treatments were used: (1) no Zn fertilization; (2) soil fertilization at transplanting; (3) Zn soil fertilization at transplanting and flowering; (4) foliar application during grain filling; (5) foliar applications during tillering, flowering, and grain filling; and (6) combination of treatment number 3 and 5. None of these treatments gave good results. Compared to the control, foliar Zn application at three growth stages significantly increased shoot biomass. Dubey *et al.* [6] conducted an experiment with three levels of nitrogen *i.e.* 60, 120 and 180 kg N/ha and S 20, 40 and 60 kg/ha along with two levels of Zn 5 and 10 kg/ha and reported that application of Zn substantially increased grain and straw yield and maximum grain and straw yield (56.55 and 79.16 q/ha) was recorded with 10 kg Zn/ha but there was no any significant increment was found upto 5 kg Zn/ha. Haque *et al.* (2015) planned an experiment to evaluate the long-term effects of S and Zn fertilization on rice yield and nutrient efficiency, level of chemical fertilizers in NPKSZn treatment were applied with the rates of N-P-K-S-Zn as 80–25–35–20–5 kg/ha and 120–25–35–20–5 kg/ha in the wet and dry seasons, respectively and find that Zn fertilization was not effective in increasing grain yield in the wet season and increased only 3% in the dry season. Four level of Zn (0, 5, 10 and 15 kg Zn/ha) as soil addition and three level of (0, 0.5 and 1 %) $ZnSO_4$ solution (0, 5 and 10 g $ZnSO_4$ per liter of de-ionized water) as foliar application and concluded that Both soil addition and foliar spray of $ZnSO_4$ significantly increased grain yield and test weight, while its effect on biological yield was found non-significant [11]. Mahmudi *et al.* [16] conducted an experiment with four level of K doses (0, 50, 100 and 150 kg/ha) and Zn fertilization at three levels (0, 30 and 60 kg/ha). They evaluated that grain yield was not increases significantly with increase Zn fertilization. However, the highest grain yield was observed in the treatment of 60 kg Zn/ha. Rana and Kashif [27] concluded maximum straw and grain yield was obtained when Zn-EDTA was applied @ 10.00 kg/ha in soil. Muamba and Ambara [18] planned an experiment with three zinc levels (0, 20 & 30 kg/ha $ZnSO_4$) and they reported maximum effective tillers m^{-2} and grain yield with 30 kg/ha of $ZnSO_4$.

Hussain *et al.* [10] in an experiment found that various Zn application methods to study Zn biofortification in wheat grain grown in a calcareous soil under glasshouse conditions. Wheat was treated with different Zn applications to soil (0, 4.5 or 9 mg Zn/kg), seed (100mL of either 0 or 6.75 % Zn w/v sprayed on 1 kg seed) and foliage (distilled-water-sprayed control, 1mL of 0.05 % Zn w/v at jointing, 2×1 mL of 0.50 % Zn w/v at heading or combined jointing and heading sprays) in all possible combinations. Phattarakul *et al.* [23] planned an experiment and shown the effect of soil and/or foliar Zn fertilizer application on grain yield and found that Zn application increased grain yield by about 5 %. Pooniya *et al.* [24] conducted an experiment to examine the effects of summer green manuring crops and zinc fertilization on soil nutrient dynamics and productivity of basmati rice. They found that application of 2.0% ZEU as $ZnSO_4$. H_2O shown the highest basmati rice grain yield (3.79 t /ha) and the increase was registered to the tune of 12.78%, 2.43%, 3.26%, 5.71%, 7.05% and 5.27% over control (only N), 2.0% ZEU as ZnO, 5 kg Zn/ha as $ZnSO_4$ .H_2O, 5 kg Zn/ha as ZnO, 0.5 kg Zn as ZnO slurry and 1.0 kg Zn through 0.2% foliar spray, respectively. Zou *et al*. [34] combined the application of soil and foliar Zn application increased grain yield whereas foliar Zn application did not cause any adverse effect on grain yield and even slightly improved the yield. Pooniya *et al* [24] showed that application of 2.0% Zn-enriched urea (ZEU) as $ZnSO_4$. H_2O significantly influenced yield attributes and yield of basmati rice. Muthukumararaja and Sriramachandrasekharan [20] recorded maximum panicle m^{-2}, Grains panicle^{-1}, above ground biomass, grain , test weight and harvest index with application of Zn at 6 kg/ha. Keram *et al*. [12] reported that application of 10 kg Zn/ha was statistically at par to 20 kg Zn/ha in grain yield, straw yield and harvest index. Rahman *et al*. [26] conducted an experiment and found that significant increases in grain yield, straw and grain Zn contents with foliar application of Zn as Zn-EDTA and $ZnSO_4$, but the highest increase was observed with Zn-EDTA application. Shivay *et al* [29] in an experiment found that effect of zinc fertilization on yield attributes of rice, when 2% Zn-coating with zinc sulfate ($ZnSO_4.7H_2O$) was applied significantly increase partial factor productivity of applied Zn varied from 984-3387 kg grain kg/Zn, agronomic efficiency varied from 212-311 kg grain kg/Zn (applied) and physiological efficiency of Zn varied from 6,384-17,077 kg grain kg/Zn (absorbed). Thus, excess Zn fertilization of basmati rice can lead to higher grain yield and Zn-denser grains. Mustafa *et al.* [19] conducted an experiment to examine the effect of different methods and timing of zinc application on growth and yield of rice. They reported method and timing of zinc application had significantly effect on paddy yield and maximum paddy yield was achieved in basal application at the rate of 25 kg/ha and minimum paddy yield was noted in foliar application at 75 DAT with 0.5% Zn solution. Saeed *et al.* [28] conducted experiment with eight treatments viz. control, rice nursery root dipping in 0.5 % Zn solution, $ZnSO_4$ application at the rate of 25 kg/ha as basal dose, foliar application of 0.5 % Zn solution at 15, 30, 45, 60 and 75 days after transplanting, and they reported maximum productive tillers per m^{-2} (249.80) and yield (5.21 t/ha) with basal application at the rate 25 kg/ha (21 %) $ZnSO_4$ and minimum yield and productive tillers per m^{-2} (220.28) were recorded with foliar application at 60 DAT @ 0.5 % Zn solution. Sridevi *et al*. [31] reported the effect of recommended dose of NPK +200 kg FYM enriched with 5.0 kg zinc, increased the grain and straw yields due to increased availability of zinc. Naik and Das [21] showed that split applications of 10 and 20 kg Zn/ha as $ZnSO_4$ recorded 7.3 and 6% more grain yield respectively, over their corresponding basal application (10 and 20 kg Zn/ha at basal). However, basal application of Zn-EDTA (1.0 kg Zn/ha through EDTA) resulted in a 2.8% increase in grain yield compared with its corresponding split applications (Zn 1.0 kg as Zn-EDTA in two splits). Kumar and Kumar [14] planned an experiment to study the effect of rates and methods of zinc application in rice under flood prone conditions. There was a significant increase in yield and yield attributes of rice up to 45 kg $ZnSO_4$ per ha. Soil applied Zn proved superior as compared to its foliar application. Mandal *et al.* [17] advocated that, application of 10 kg Zn (5.0 + 2.5 + 2.5 kg/ha) in three splits in combination with recommended dose of NPK found significantly higher yield attributes, grain and straw yield.

CONCLUSION

Plant growth characters comprise of plant height, number of tillers, number of leaves, dry matter accumulation and leaf area index (LAI) which together contribute for the growth of plant and finally to the crop yield. For the growth and development of the all plant the zinc is the one of the most micronutrient as improper application zinc application lead to the improper growth of the plant. So zinc should be applied at proper dose and at appropriate growth stages. For optimizing the yield of rice zinc should be applied as soil application or combination with the foliar application at appropriate growth stage for boosting the yield potential of the rice.

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