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Short-term Zinc Biofortification effects on Morpho-economic Parameters of Rice in Rice-wheat Sequence in Inceptisols of Jammu, J&K

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ABSTRACT: In order to address the issue of zinc deficiencies in rice crops, which are common in Jammu soils (known as inceptisols), different types and levels of zinc fertilizers are applied to the rice crop to determine their effectiveness in such soil conditions. The goal is to find the most suitable zinc fertilizer sources and application methods for such crop. A field trial comprising three different sources of zinc viz. zinc sulphate, zinc oxide and zinc chelate each with two levels of zinc (Zn), were applied both as soil and foliar application in rice cultivar (Pusa-1121). The experiment was carried out during the monsoon season of 2020 and 2021 at field research station of Division of Soil Science and Agricultural chemistry SKUAST-Chatha, Jammu. The treatment combination consisted of seven treatments *viz.* T_1-Soil Application of $ZnSO_4.7H_2O$ (12.5 kg ha^{-1} + Foliar Spray 1.6 %), T_3-Soil Application of ZnO (5 kg ha^{-1} + Foliar spray 0.50 %), T_4-Soil Application of ZnO (5 kg ha^{-1} + Foliar spray 0.65 %), T_5-Soil Application of Zn-EDTA 10 kg ha^{-1} + Foliar spray 1.0 %), T_6-Soil Application of Zn-EDTA-chelate 12.5 kg ha^{-1} + Foliar spray 1.5 %) and T_7 – Control and were replicated thrice in randomized complete block design. Each plot measured 3.0 m × 2.0 m (6 m^2), with plant spacing of 20 cm × 10 cm between rice seedlings. Fertilizers were applied on basis as per the recommended nutrient requirement of basmati Pusa-1121 (N:P:K). Short term effect of zinc biofortification was studied on morpho-economic parameters of rice *viz*., plant height, Number of effective tillers, grain yield, straw yield and dry matter accumulation at harvest. Zn EDTA-chelate at 12.5 kg ha^{-1} along with foliar application @ 1.5 % proved to best treatment and recorded significantly higher plant height, effective tillers m^{-2}, grain yield, straw yield and dry matter accumulation. The percentage increase of 16.7, 18.82, 10.10, 12.3 and 15.43 were registered among all respective parameters as compared to control, whereas treatment T_2-Soil Application of $ZnSO_4.7H_2O$ 15 kg ha^{-1} + Foliar spray 2.5 %), and T_5-Soil Application of Zn -EDTA 10 kg ha^{-1} + Foliar spray 1.0 %) were statistically at par with treatment T_6-Soil Application of Zn-EDTA-chelate 12.5 kg ha^{-1} + Foliar spray 1.5 %).

Keywords: Zinc, Biofortification, Morphoeconomic parameters, Yield attributes.

INTRODUCTION

Rice is the primary source of sustenance for over half of the global population, with cultivation occurring over an area of approximately 158.8 million hectares and an annual production of 751.9 million tons (FAO, 2017). India is the largest producer of rice after China, contributing to 21.5% of global rice production. Rice occupies 25% of the total cropped area in India, contributing 40-43% to total food grain production and is an essential element in the national food and livelihood security system. In India, rice is grown on 43.19 million hectares, with an annual productivity of 110.15 million tons and a yield of 2.55 quintals per hectare (Annual Report, 2017-18).

The state of Jammu and Kashmir has been growing rice as the most important staple food crop from time immemorial. The total rice area of the state is around 0.28 million hectares, with an annual production of 0.55 million tons and a yield of 2.1 tons per hectare (DES, 2018). Rice, specifically *Oryza sativa* L., is the staple food for 50% of the global population. In the financial year 2019, the yield of rice across India was estimated to be approximately 2.6 thousand kilograms per hectare. The increasing Indian population demands more production of rice across the country. However, rice grain is relatively lower in some micronutrients, such as Zinc (Zn), compared to other staple crops, including wheat, maize, and legumes. Zn and Iron (Fe) deficiency in rice can be mitigated through fertilization, which is deemed a cost-effective method to alleviate Zn and Fe malnutrition (Zhou *et al.,* 2012). Application of Zn fertilization to cereal crops enhances productivity and grain Zn concentration, thereby contributing to the grain's nutritional value for human consumption. Researchers have reported the use of ($ZnSO_4$ at 25 kg ha^{-1} + 0.5% foliar application) which produced remarkably higher numbers of effective tillers meter^{-2}, grains panicle^{-1}, filled grains panicle^{-1}, and length of the panicle (cm) in comparison to other treatments (Barua and Saikia 2018). Basal soil application of 25 kg $ZnSO_4$ ha^{-1} produced a higher grain yield (50.05 q ha^{-1}) than foliar spray of 0.2% $ZnSO_4$ at two different stages, namely panicle initiation and flowering stage, as compared to the control (Sinha *et al*., 2018). Zinc application at 20-25 kg ha^{-1} to maize has also been reported (Ariraman *et al*., 2022). Furthermore, combined application of $ZnSO_4$, $FeSO_4$, and foliar application of Zn-EDTA, Fe-EDTA (Rao *et al*., 2019) has been reported in the literature. (Pedler *et al*., 2000), zinc plays a crucial role in connecting certain enzymes such as alcohol dehydrogenase, carbonic anhydrase, and superoxide dismutase. In addition to aiding in plant enzyme formation, zinc also activates numerous enzymatic reactions. It is evident that zinc is a vital nutrient for enzymatic processes. The scarcity of Zinc is more widespread, particularly in the northern region of India where rice and wheat are cultivated in rotation. Rice, grown in submerged conditions, has a higher requirement for Zinc as the availability of other nutrients increases under flooded conditions, thereby decreasing the availability of Zinc to crops. Recent estimates indicate that almost half of the world's population suffers from a shortage of Zinc, which could be attributed to the widespread scarcity of Zinc in soils worldwide (Cakmak, 2008). Approximately 49 percent of soils in India have a lack of Zinc, and this number is expected to increase to 63 percent by 2025 Arunachalam *et al.* (2013). Saha *et al.* (2013) conducted a study and found that the application of Zinc through soil and foliar methods resulted in a noteworthy increase in plant height of rice crops when compared to the control. The study results also indicated that there was a height increase of 3.6% and 7.3% with soil and foliar applications of Zinc, respectively, in comparison to the control.

The present study aimed to investigate the short-term effect of zinc-biofortification on morpho-economic parameters of rice, an essential cereal worldwide. As the world's population continues to increase, the demand for rice production rises. However, the nutritional value of rice must be enhanced, particularly concerning the micronutrient content. Zinc fertilization can provide a cost-effective and practical method to alleviate zinc deficiency in rice and improve the nutritional value of this crucial staple food crop.

MATERIALS AND METHODS

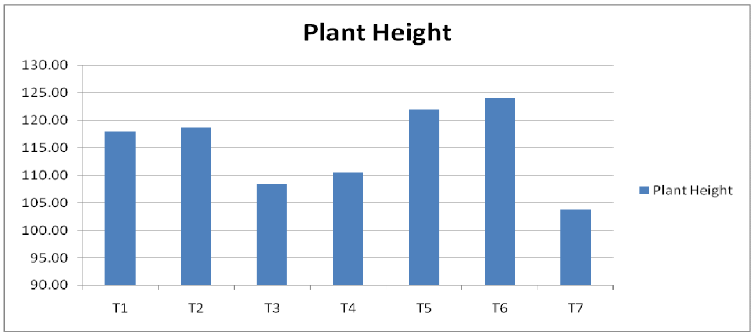
A field trial was conducted in research farm at main campus of the SKUAST-Jammu, J and K (UT), located in the North-Western plains of Jammu, near to the Shivalik range of hills, at 32°39'33"N latitude and 74°48'45"E longitude, at an elevation of 332 metres above mean sea level. The experiment consisted of 7 treatments wherein various zinc sources were applied as both Soil and foliar such as, zinc sulphate heptahydrate, zinc oxide and zinc chelated. Each treatment was replicated thrice, in a randomized block design. (Table 1). Each plot measured 3.0 m × 2.0 m (6 m^2), separated by 0.5 m bund, with plant spacing of 20 cm × 10 cm between rice seedlings. Fertilizers were applied on basis as per the recommended nutrient requirement of Basmati cultivar -Pusa-1121 (N:P:K 45:30:15). Various morpho-economic plant parameters *viz*., plant height, No of effective tillers, grain yield, straw yield and dry matter accumulation were recorded and mean values were calculated for two years at harvest .The aim of our study was to look over the direct effects of different sources and methods of zinc application on plant parameters and also their effects on yield attributes in rice crop. The outcomes, of this research will help us to attenuate the zinc deficiency in rice crop and also helps us to ameliorate the zinc use efficiencies in paddy.

Table 1: Treatment details of Zinc fertilizers.

Sr. No.	Treatment combinations
T_1	RDF + Soil Application of $ZnSO_4.7H_2O$ (12. 5 kg /ha) + Foliar. S (1.6 %).
T_2	RDF + Soil Application of $ZnSO_4.7H_2O$ (15 kg /ha) + Foliar.S (2.5 %).
T_3	RDF + Soil Application of ZnO (5 kg /hectare) +Foliar. S (0.50 %).
T_4	RDF + Soil Application of ZnO (5 kg /hectare) +Foliar. S (0.65 %).
T_5	RDF + Soil Application of Zn -EDTA (10Kg/ha) + Foliar spray of (1.0 %).
T_6	RDF + Soil Application of Zn-EDTA (12.5 Kg/ha) + Foliar spray of (1.5 %).
T_7	RDF (Control)

RESULTS AND DISCUSSION

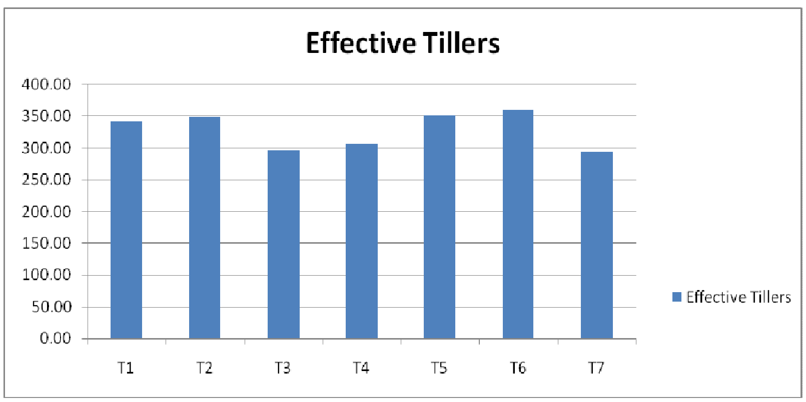
Plant Height. There was significant difference in plant height amongst the treatments (Fig. 1). The maximum plant height was obtained in treatment T_6 (122.37) cm and exhibited 15.7 % increase in plant height as compared to control where, no zinc was applied. The treatment no T_6 (Soil Application of Zn-EDTA (12.5 kg ha^{-1} + Foliar spray of 1.5 %). Treatment was significantly superior amongst all treatments and was statistically at par with T_5 (soil Application of Zn -EDTA (10 kg ha^{-1} + Foliar spray of 1.0 %) and T_2 (Soil Application of $ZnSO_4.7H_2O$ 15 kg ha^{-1} + Foliar spray of 2.5 %). The plant height increased significantly with combined soil and foliar application of zinc Chelate along with recommended dose of fertilizers. It might be due to availability of sufficient nutrients that promotes improved crop growth and better root development. The Zn accelerates the enzymatic activity and auxin metabolism in crops. The results are in agreement with Khan *et al.* (2007); Humaira *et al.* (2015); Ram *et al.* (2011); Boonchuay *et al.* (2013); Mandal *et al.* (2009); Sudhagar *et al.* (2019) stated that the significant increase in plant height might be because of the internodes elongation and vigorous root growth, resulted in increase in protein synthesis and cell growth.



T_1-Soil Application of $ZnSO_4.7H_2O$ (12. 5 kg /ha) + Foliar. S (1.6 %). **T_2**-Soil Application of $ZnSO_4.7H_2O$ (15 kg /ha) + Foliar. S (2.5 %). **T_3**-Soil Application of ZnO (5 kg /hectare) + Foliar. S (0.50 %). **T_4**-Soil Application of ZnO (5 kg /hectare) + Foliar. S (0.65 %). **T_5**-Soil Application of Zn-EDTA (10Kg/ha) + Foliar spray of (1.0 %). **T_6**-Soil Application of Zn-EDTA (12.5 Kg/ha) + Foliar spray of (1.5 %). **T_7**-Control (RDF).

Fig. 1. Effect of zinc biofortification on plant height (cm) in rice crop.

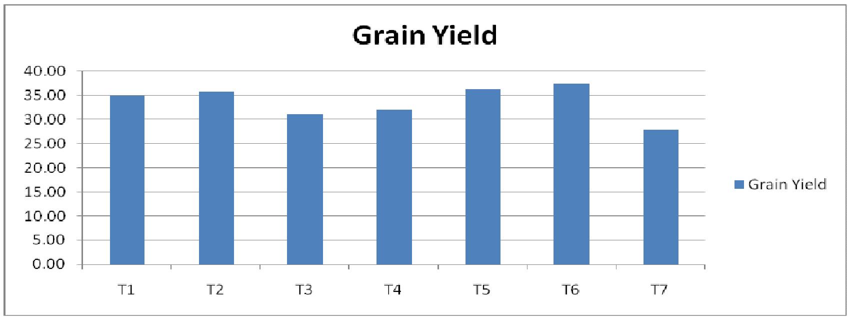
Effective tillers m^{-2}. The data furnished in the (Fig. 3) revealed that the maximum no of effective tillers per meter square was observed in treatment T_6 (Soil Application of Zn-EDTA 12.5 kg ha^{-1} + Foliar spray of 1.5%) is 360.32 unit with respect to the treatment no T_7 (control) is 292.54 units and reveals 18.82 %increase with respect to T_7 (control) where, no zinc was applied. The treatment no T_6 was significantly superior to the rest of the treatments and at par with treatment no T_5 (Soil Application of Zn -EDTA 10kg ha^{-1} + Foliar spray of 1.0 % and treatment T_2 (Soil Application of $ZnSO_4.7H_2O$ 15 kgha^{-1} + Foliar. S 2.5 %. The above result may be due to the soil and foliar application of zinc chelate which facilitated more number of effective tillers m^{-2} in rice crop (Mustafa *et al.,* 2013); Rehman *et al*. (2012); Sudhagar *et al.* (2019) observed that the increase in no. of effective tillers m^{-2} might be due to increased photo synthetic rate, excessive accumulation of sucrose, glucose and fructose in leaves and also fixation of nitrogen which may support in increased physiological parameters of the plant.



T_1-Soil Application of $ZnSO_4.7H_2O$ (12. 5 kg /ha) + Foliar. S (1.6 %). **T_2**-Soil Application of $ZnSO_4.7H_2O$ (15 kg /ha) + Foliar. S (2.5 %). **T_3**-Soil Application of ZnO (5 kg /hectare) + Foliar. S (0.50 %). **T_4**-Soil Application of ZnO (5 kg /hectare) +Foliar. S (0.65 %). **T_5**-Soil Application of Zn-EDTA (10Kg/ha) + Foliar spray of (1.0 %). **T_6**-Soil Application of Zn-EDTA (12.5 Kg/ha) + Foliar spray of (1.5 %). **T_7**-Control (RDF).

Fig. 2. Effect of zinc biofortification on Effective tillers m^{-2} in rice crop.

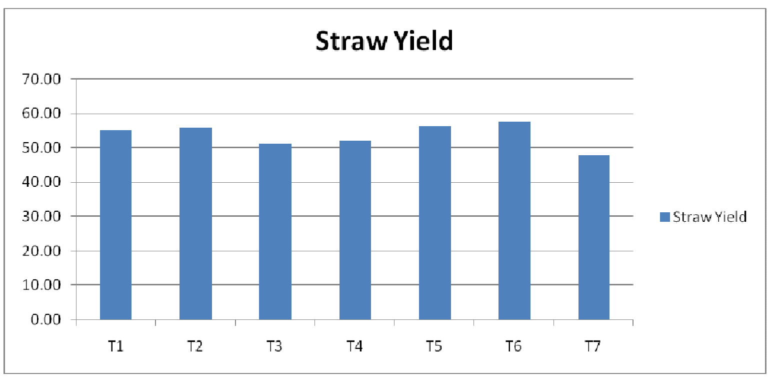
Grain Yield. While as in terms of grain yield the above Fig. 3 shows that the highest grain yield was obtained in treatment T_6 (Soil Application of Zn-EDTA (12.5 kg ha^{-1}) + Foliar spray of 1.5%) was 36.18 quintals per hectare with respect of the control T_7 is 26.17 and an increase over 10.10 % with respect of the control where, no zinc and iron were applied. The T_6 treatment was significantly on higher side to the rest of the treatments and at par with T_5 Soil Application of Zn -EDTA (10 kg ha^{-1}) + Foliar spray of (1.0 %) and T_2 (Soil Application of $ZnSO_4.7H_2O$ (15 kg ha^{-1}) + Foliar spray 2.5 %). It might be due to the soil and foliar application of zinc chelate. This result is in arrangement with the finding of Karak *et al*. (2005); Barua and Saika (2018); Cakmak (2008); Saha *et al.* (2013); Sudhagar *et al.* (2019) also found that it may be due to the catalytic or stimulatory effect of zinc on most of the physiological and metabolic process of plants and biosynthesis of IAA, which indirectly results in initiation of primordial reproductive part and portioning of photosynthetic towards them which ultimately promotes the grain yield.



T_1-Soil Application of $ZnSO_4.7H_2O$ (12. 5 kg /ha) + Foliar. S (1.6 %). **T_2**-Soil Application of $ZnSO_4.7H_2O$ (15 kg /ha) + Foliar. S (2.5 %). **T_3**-Soil Application of ZnO (5 kg /hectare) + Foliar. S (0.50 %). **T_4**-Soil Application of ZnO (5 kg /hectare) +Foliar. S (0.65 %). **T_5**-Soil Application of Zn-EDTA (10Kg/ha) + Foliar spray of (1.0 %). **T_6**-Soil Application of Zn-EDTA (12.5 Kg/ha) + Foliar spray of (1.5 %). **T_7**-Control (RDF).

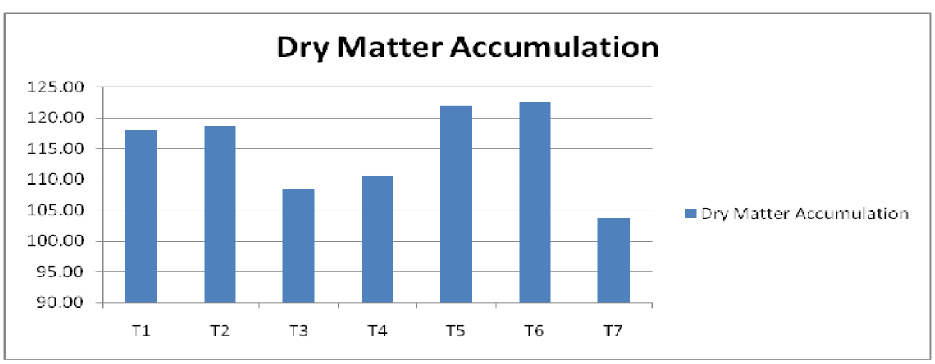
Fig. 3. Effect of Zinc biofortification on grain Yield (q ha^{-1}) in rice crop.

Straw Yield. The highest straw yield shown by the Fig. 4 indicates that significantly higher straw yield in treatment T_6 (Soil Application of Zn-EDTA (12.5 kg ha^{-1}) + Foliar spray of 1.5% is 56.19 units while as shows higher straw yield in other treatments with respect to T_7 (control), where, no zinc and iron were applied. The T_6 treatment was significantly on higher side to the rest of the treatments but on par with treatment no T_5 (Soil Application of Zn-EDTA (10 kg ha^{-1}) + Foliar spray of 1.0 %) and T_2 (Soil Application of $ZnSO_4.7H_2O$ (15 kg ha^{-1}) + Foliar. S 2.5 %. The treatment no T_6 shows an increase in This may be due to the to better performance of growth and yield parameters through adequate availability of major and micro nutrients in soil, which in turn, favorably influenced physiological processes and build-up of photosynthates, and these results are in close conformity with the Tabassum *et al.* (2013). The commendatory effect of Zn-EDTA on the proliferation of roots thus helps in increasing the uptake of the plants nutrients from the soil supplying in to the aerial parts of the plant and ultimately enhancing the overall growth of the plant (Barua and Sakia 2018); Cakmak (2008); Saha (2013); Sudhagar *et al.* (2019).



T_1-Soil Application of $ZnSO_4.7H_2O$ (12. 5 kg /ha) + Foliar. S (1.6 %). **T_2**-Soil Application of $ZnSO_4.7H_2O$ (15 kg /ha) + Foliar. S (2.5 %). **T_3**-Soil Application of ZnO (5 kg /hectare) + Foliar. S (0.50 %). **T_4**-Soil Application of ZnO (5 kg /hectare) +Foliar. S (0.65 %). **T_5**- Soil Application of Zn-EDTA (10Kg/ha) + Foliar spray of (1.0 %). **T_6**-Soil Application of Zn-EDTA (12.5 Kg/ha) + Foliar spray of (1.5 %). **T_7**-Control (RDF).

Fig. 4. Effect of zinc biofortification on Straw Yield (q ha^{-1}) in rice crop.



T_1-Soil Application of $ZnSO_4.7H_2O$ (12. 5 kg /ha) + Foliar. S (1.6 %). **T_2**-Soil Application of $ZnSO_4.7H_2O$ (15 kg /ha) + Foliar. S (2.5 %). **T_3**-Soil Application of ZnO (5 kg /hectare) + Foliar. S (0.50 %). **T_4**-Soil Application of ZnO (5 kg /hectare) + Foliar. S (0.65 %). **T_5**-Soil Application of Zn-EDTA (10Kg/ha) + Foliar spray of (1.0 %). **T_6**-Soil Application of Zn-EDTA (12.5 Kg/ha) + Foliar spray of (1.5 %). **T_7**-Control (RDF).

Fig. 5. Effect of zinc biofortification on dry matter accumulation (q ha^{-1}) in rice crop.

Dry matter Accmulation. The data pertaining to dry matter production was furnished in the (Fig. 5) stated that the best treatment in terms of dry matter production was treatment T_6 with respect of the all other treatments. The highest dry matter production was found in T_6 (Soil Application of Zn-EDTA (12.5 kg ha^{-1}) + Foliar spray of 1.5%) is 122.70 units with respect to the treatment no T_7 (control) is 103.77 units while as in percentage it was of 15.43 % with respect to the control. Treatment T_6 was significantly best treatment but was at par with treatment T_1 (Soil Application of $ZnSO_4.7H_2O$ (12. 5 kg ha^{-1}) + Foliar spray (1.6 %), T_2 (Soil Application of $ZnSO_4.7H_2O$ (15 kg /ha) + Foliar spray (2.5 %) and T_5 (Soil Application of Zn -EDTA 10 kg ha^{-1} + Foliar spray of 1.0 %). The combined application of both soil and foliar of zinc chelate had helped towards balanced availability of nutrients throughout the crop growth period. The enhanced availability of nutrients especially zinc under aerobic conditions might have leaded to better accumulation of photosynthates in the form of dry matter. These results were in accordance with Pal *et al*. (2008); Karak (2005); Dhaliwal *et al*. (2009); Khan *et al*. (2012); Naik and Das (2008); Sudhagar *et al.* (2019). Observed that RDF as soil application along with Zn-EDTA resulted in distribution of nutrients within the rice plant that occurs through xylem and re-translocation in phloem which increases vegetative tissue formation resulted in improved photosynthetic activity which exhibit boosted growth of the plant parts and increase in dry matter.

CONCLUSIONS

The treatment T_6 (Soil Application of Zn-EDTA (12.5 kg ha^{-1}) + Foliar spray of 1.5%) in terms of plant parameters as well under yield attributes, but was statistically at with treatment T_5 (Soil Application of Zn -EDTA 10 kg ha^{-1} + Foliar spray of 1.0 %). However, treatment T_1 (Soil Application of $ZnSO_4.7H_2O$ (12. 5 kg ha^{-1}) + Foliar spray (1.6 %) also shows better performance under such conditions, so it has equally potential to perform better in terms zinc biofortification point of view and also zinc sulphate is economically viable from farmers point of view as it easily available and cheapest among all the zinc fertilizers.

However, in order to ensure the success of zinc biofortification interventions, it is important to implement policies such as providing financial incentives to farmers, offering capacity building and awareness programs for farmers, seed multipliers, and rural communities to educate them on balanced crop fertilization (micronutrients such as Zn), Additionally, subsidizing Zn fertilizer products for farmers and also foliar application should be at the precise time when the crop is in need of it, Zinc fertilizer soil application should be added with the organic manure so as to increase the efficiency of such fertilizers.

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Conflict of Interest. Zinc plays a crucial part in enhancing the overall potential of cereal crops, and conducting such kind of research can aid in reducing zinc deficiency in the population masses, which suffers its deficiency as well as ensuring an equilibrium of zinc in the soil.

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