Study The Effect of Different Levels of Zinc on Rice

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***Abstract*—Zinc is one of the micronutrients that is essential for plants' proper growth and development. The study examined the impact of zinc fertilizer on rice variety ADT-43 at Annamalai University's Experimental Farm in Tamil Nadu, India, in order to ascertain the impact of varying zinc levels on rice growth and output. During the kuruvai season (June–September 2023), this study examined the impact of several zinc sources on the growth and yield of transplanted rice. Each of the ten treatments used varying amounts of zinc fertilizers. Randomized block design (RBD) was used in the design of the field trial, and three separate trials of the treatments were conducted. The experiment revealed that grain and straw yield was significantly enhanced on addition of different zinc, inorganics and their combinations over control. The highest grain and straw yield were obtained with combined application of 100% RDF + Soil application of Zn-EDTA @ 5kg ha^{-1} + Foliar spray of nano Zn @ 0.2%. The addition of 100% RDF + Soil application of Zn-EDTA @ 5kg ha^{-1} + Foliar spray of nano Zn @ 0.2% resulted in significant increase in higher value for yield attributes (number of panicles m^{-2}, number of filled grains panicle^{-1}, panicle length). Based on the study, revealed Zinc and inorganic fertilization were found to be effective materials for increasing soil fertility and crop productivity.**

***Index Terms*—Growth, rice, zinc sulphate, zinc oxide, nano zinc, yield**

I. INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most important field crops after wheat consumed as a staple and an indispensable source of calories for almost half of the population due to its every day consumption in Asia (Singh *et al*., 2020). Rice plays an important role in Indian agriculture, which is the staple food for more than 60% of the population. Globally rice cultivated over an area of 165.67 million hectares with a production of 520 million metric tonnes and the productivity of 4.69 t ha^{-1}. In India, rice is cultivated across an area of 47.60 million hectares with a total production 137.00 million metric tonnes and a productivity of 4.32 t ha^{-1} (USDA, 2024). In Tamil Nadu, rice is grown on 2.03 million hectares, with a production of 7.44 Mt and a productivity rate of 3.38 t ha^{-1} respectively, (Indiastat, 2020-21). Over the past many years, both in India and worldwide, there has been a notable increase in macro and micronutrient deficiencies in crops and soil (Shukla *et al*., 2021). High-yielding crop types (Shukla *et al*., 2018), increasing cropping intensity (Behera *et al*., 2021), and decreased or nonexistent use of organic manures are the main causes of the rise in these deficiencies. A disproportionate reliance on the overuse of chemical fertilizers, particularly nitrogen (Upadhyay *et al*., 2022), in agricultural methods has been apparent recently due to the growing population's desire for food. Although fertilizer application notably improved the crop development and elevated the yields of numerous crops but the yields got plateaued due the low fertilizer response ratio, uneven fertilization and rising intensities of micro-nutrient deficiencies across the country (Lahari *et al*., 2021). Nitrogen is most important element required for plant growth and development. Nitrogen facilitates the usage of P, K, and other elements in plants. It is a component of protein, nucleic acid, and other molecules important for plant growth. Phosphorus plays a key role in photosynthesis, the metabolism of sugars, energy storage and transfer, cell division, cell enlargement and transfer of genetic information. According to Sustr *et al*. (2019), potassium has a number of direct and indirect roles in photosynthetic activity and plant growth. A sufficient supply of potassium facilitates improved nutrient absorption and photosynthetic assimilation.

In India, zinc deficiency remains a major determinant of crop productivity among all the micronutrients. Crops require very little zinc for normal growth, but because of their extremely low fertilizer usage efficiency which ranges from 1-3 to 5-8% for soil and foliar application their application rate is considerable (Ram *et al*. 2020). Zinc chelates, like zinc ethylene diamine tetra acetic acid (Zn-EDTA), are another source of Zn that plants can receive in large amounts without interacting with soil particles. Therefore, the combined application of soil and foliar Zn application is considered the best sustainable strategy for optimal yield and agronomic biofortification (Chattha *et al*., 2017). Compared to conventional zinc fertilizers, zinc oxide nanoparticles (ZnO NPs) have a higher specific surface area and surface activity and are more easily absorbed and used by the rice root system (Zhang *et al*., 2021). Nano zinc is essential in keeping enough available zinc in soil solution, maintaining adequate zinc transport to seeds and increases the yield up to 38 % (Theerthana *et al*. 2022). Therefore, researchers in agriculture aim to achieve sustainable agriculture with higher yields while also protecting the health of the ecosystem and soil.

II. MATERIALS AND METHODS

A field experiments were carried out to examine how to maximize rice productivity under zinc sources at the Experimental Farm of the Department of Agronomy at Annamalai University in Tamil Nadu, India, during *kuruvai* season (June – September 2023). The experimental site is situated at an altitude of +5.79 m above mean sea level, at 11°24’N latitude and 79°44’E longitude. The experimental soil was clay loam in texture with pH 7.4, EC 0.33 ds/m, organic carbon 0.56 and low N (210 kg/ha), medium in P (18 kg/ha) and high in K (264 kg/ha). Ten treatments were used in this experiment, each of which was replicated three times, T_1 was the Control, 100% RDF (T_2), 100% RDF + Soil application of $ZnSO_4$ @ 25 kg ha^{-1} (T_3), 100% RDF + Soil application of Zn-EDTA @ 5kg ha^{-1} (T_4), 100% RDF + Foliar spray of ZnO_2 @ 0.5% at active tillering and panicle initiation (T_5), 100% RDF + Foliar spray of Zn @ 0.2% at active tillering and panicle initiation (T_6), 100% RDF + Soil application of $ZnSO_4$ @ 25 kg ha^{-1} + Foliar spray of ZnO_2 @ 0.5% at active tillering and panicle initiation (T_7), 100% RDF + Soil application of $ZnSO_4$ at 25 kg ha^{-1} + Foliar spray of nano Zn @ 0.2% at active tillering and panicle initiation (T_8), 100% RDF + Soil application of Zn-EDTA @ 5kg ha^{-1} + Foliar spray of ZnO_2 @ 0.5% at active tillering and panicle initiation (T_9), 100%RDF + Soil application of Zn-EDTA @ 5kg ha^{-1} + Foliar spray of nano Zn @ 0.2% at active tillering and panicle initiation (T_{10}). Fertilizers were applied on basis as per the recommended nutrient requirement of NPK (120:40:40 kg/ha). The aim of study was to look over the direct effects of zinc sources and the methods of zinc application on plant parameters and also their effect on yield attributes in rice crop. The results of the study will assist us in improving the efficiency of zinc utilization in paddy and in reducing the zinc shortage in rice crop.

III. RESULTS AND DISCUSSION

The yield attributes *viz.*, number of panicles m^{-2}, number of filled grains panicle^{-1} and panicle length of rice were significantly influenced by the application of 100% RDF+ soil application of Zn-EDTA 5 kg ha^{-1} + Foliar spray of Nano zinc 0.2% (Table.1) The increase in values on yield components might be due to increased nutrient absorption results in more dry matter buildup and transit to the sink. The effective assimilate translocation to the sink might have resulted in sound grain filling, as evidenced by the largest number of filled panicles^{-1}.The increasing fertility levels led to higher grain yields. Maximum grain yield was achieved by increased number of panicles m^2, the number of filled grains panicle^{-1}, panicle length. The increased grain weight at recommended dose of NPK could be attributed to increased photosynthetic rate and translocation of photosynthates from source to sink. The adequate supply of macro and micro nutrients which inturn increased the photosynthetic activity of plants and helped to develop extensive root system. This would have helped the plants to extract more nutrients from soil results in better development of yield components. Similar results were reported by Kumar *et al*. (2017a); Maisnam and Tiwana (2021). Application of chelated zinc enhanced N and K accumulation in grains, suggesting improved nutrient use efficiency, which is crucial for increasing the yield attributes in rice. The results were in confirmation with the findings of Prakashya *et al.* (2019). The yield qualities improved when assimilates were directed more towards reproductive organs. Transferring nutrients to reproductive sinks is necessary for seed development. The availability and utilization of assimilates might have an effect on seed set and filling. Nano zinc resulted in an increase in the yield attributes, as well as improving photosynthetic efficiency and reproductive sink ability to use incoming assimilates. These results are in agreement with the work of Anshuman and rao (2021).

A. Grain and straw yield of rice

The yield potential of the rice crop is determined by the values of growth and yield attributes. Among the different treatments, application of 100 % RDF + soil application of Zn-EDTA @ 5 kg ha^{-1}+ foliar spray of Nano zinc @ 0.2% (Table.2) registered highest grain and straw yield. This might be due to the influential role played by the NPK fertilizers could intensify the photosynthesis of crops, therefore it results in higher carbohydrate formation. The proper application of NPK nutrients can help translocation and storage of carbohydrates so that the harvest index can reach a maximum which contributes the higher yield in rice. Similar types of result was observed by Paiman *et al.* (2021). This could be also attributed to ideal nutro physiological condition throughout the crop growth as a result of cumulative and synergistic effect of the above treatment combination. It also because of better nutrient uptake and efficient assimilation of applied nutrients results in more leaf area, DMP, number of productive tillers m^{-2} and number of filled grains $panicles^{-1.}$ The increase in grain content in rice might related to the presence of larger levels of zinc in soil by the application of chelated-Zn, which promotes greater absorption. The increased grain and straw production with Zn-EDTA application could be attributed to the considerably higher amount of Zn absorption. The most effective source of Zn for lowland rice production and Zn mobilization efficiency was greater with Zn-EDTA for Zn absorption by grain and straw. The improvement in yield attributes and consequent to higher yield by chelated Zn might possibly be due to enhanced synthesis of carbohydrates and proteins and their transport to the sink through efficient physiological activities in plants. The present findings are in agreement with the earlier reports of Karak *et al.* (2005) and Muthukumararaja *et al.* (2019).

The higher grain yield might be due to improved nutrient uptake by the plant, resulting in optimal growth of plant parts and metabolic processes such as photosynthesis, results in maximum accumulation and translocation of photosynthates to the plant's economic parts, results in higher yield, which might be attributed to increased source and sink strength with the foliar application of nano zinc. Similar result was reported by Benzon *et al.* (2015). Increased straw yield could also be attributed to faster absorption and translocation by plants, leading to increased photosynthesis and dry matter accumulation. This is in conformity with findings of of Aziz *et al.* (2018); Kumar *et al.* (2022).

IV. CONCLUSION

The current study compared the impacts of several Zn application techniques on rice yield in order to determine the best technology to address the issue of zinc deficiency in rice. Applying zinc using any of the techniques greatly improved grain production, straw, and rice yield parameters compared to the control. The study suggested that, 100% RDF + Soil application of Zn EDTA @ 5kg ha^{-1} + Foliar spray of nano Zn @ 0.2 % resulted in better results. The study suggests that it would be beneficial to mitigate Zn deficiency in rice and therefore, improve zinc use efficiency.

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Table.1: Effect of different sources of zinc application on yield attributes of rice

TREATMENTS	Number of panicles (m^{-2})	Number of filled grains panicle^{-1}	Panicle length (cm)
T_1 – Control	236	71.36	12.35
T_2 - 100 % RDF	268	79.42	14.42
T_3 - 100% RDF + Soil application of $ZnSO_4$ @ 25kg ha^{-1}	298	84.54	15.24
T_4 - 100 % RDF + Soil application of Zn-EDTA @ 5kg ha^{-1}	348	92.14	16.20
T_5 - 100 % RDF + Foliar spray of ZnO_2 @ 0.5 %	324	88.76	15.64
T_6 - 100 % RDF + Foliar spray of nano Zn @ 0.2%	354	92.42	16.22
$_7$ - 100% RDF + Soil application of $ZnSO_4$ @ 25 kg ha^{-1} + Foliar spray of ZnO_2 @ 0.5%	377	98.24	16.49
$_8$ -100% RDF + Soil application of $ZnSO_4$ @ 25 kg ha^{-1} + Foliar spray of nano Zn @ 0.2%	398	101.82	16.82
- 100% RDF + Soil application of Zn-EDTA @ 5kg ha^{-1} + Foliar spray of ZnO_2 @ 0.5%	423	107.80	17.10
- 100% RDF + Soil application of Zn-EDTA @ 5kg ha^{-1} + Foliar spray of nano Zn @ 0.2%	442	110.16	17.46
S. Ed±	4.3	1.40	0.31
CD (p=0.05)	8.64	2.94	0.65

Table.2: Effect of different sources of zinc application on grain and straw yield (kg ha^{-1}) and harvest index (%) of ric

TREATMENTS	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index (%)
T_1 – Control	1757	2754	38.95
T_2 - 100 % RDF	3462	5604	38.19
T_3 - 100% RDF + Soil application of $ZnSO_4$ @ 25kg ha^{-1}	3755	5946	38.71
T_4 - 100 % RDF + Soil application of Zn-EDTA @ 5kg ha^{-1}	4286	6512	39.69
T_5 - 100 % RDF + Foliar spray of ZnO_2 @ 0.5 %	4045	6230	39.37
T_6 - 100 % RDF + Foliar spray of nano Zn @ 0.2%	4358	6602	39.76
- 100% RDF + Soil application of $ZnSO_4$ @ 25 kg ha^{-1} + Foliar spray of ZnO_2 @ 0.5%	4716	6912	40.56
-100% RDF + Soil application of $ZnSO_4$ @ 25 kg ha^{-1} + Foliar spray of nano Zn @ 0.2%	5051	7224	41.15
- 100% RDF + Soil application of Zn-EDTA @ 5kg ha^{-1} + Foliar spray of ZnO_2 @ 0.5%	5402	7646	41.40
- 100% RDF + Soil application of Zn-EDTA @ 5kg ha^{-1} + Foliar spray of nano Zn @ 0.2%	5609	7896	41.53
S. Ed±	79.68	115.2	0.76
CD (p=0.05)	167	243	NS