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STUDIES ON THE EFFECT OF DIFFERENT LEVELS OF ZINC ON YIELD ATTRIBUTES, YIELD AND ECONOMICS OF 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 yield and economic viability during the *Kuruvai* season (June–September, 2023). The experiment was carried out with 10 treatments consist of varying levels of zinc and replicated thrice in Randomised Block Design (RBD). The experiment revealed that grain, straw yield and economics was significantly enhanced by the addition of different zinc, inorganics and their combinations over control. The application of 100% RDF + Soil application of Zn-EDTA @ 5kg ha^{-1} + Foliar spray of nano Zn @ 0.2% resulted in significantly higher value for yield attributes (number of panicles m^{-2}, number of filled grains $panicle^{-1}$, panicle length), yield and economic returns. Based on the study, it is concluded that the Zinc and inorganic fertilization were found to be effective amendments for increasing soil fertility and crop productivity.
Keywords: Zinc sulphate, Zinc oxide, Nano zinc, Zinc-EDTA, Rice yield

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 everyday 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 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 productivity of 4.32 t ha^{-1}. 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. Over the past, 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 increasing cropping intensity (Behera *et al*., 2021) and decreased or non-existent use of organic manures are the main causes of the rise in these deficiencies. A disproportionate reliance on the chemical fertilizers, particularly nitrogen (Upadhyay *et al*., 2022) in agricultural methods has been increasing 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 factor limiting crop productivity among all the micronutrients. Although crops require only small amounts of zinc for normal growth, their extremely low fertilizer usage efficiency ranging from 1-3% for soil application and 5-8% for foliar application necessitates a considerable application rate (Ram *et al.,* 2020). Zinc chelates, such as zinc ethylenediaminetetra acetic acid (Zn-EDTA), provide plants with significant amounts of zinc without interacting with soil particles. Therefore, the combined application of soil and foliar Zn is considered the most sustainable strategy for achieving 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 greater surface activity, making them more easily absorbed and utilized by the rice root system (Zhang *et al.,* 2021). Nano zinc plays a crucial role in maintaining adequate zinc availability in the soil solution, ensuring sufficient zinc transport to seeds, and increasing yield by up to 38% (Theerthana *et al.,* 2022). Therefore, researchers in agriculture aim to achieve sustainable agriculture with higher yields while protecting the health of the ecosystem and soil.

Materials and Methods

A field experiments were carried out to examine how to maximize rice productivity under different zinc sources at the Experimental Farm, Department of Agronomy at Annamalai University in Tamil Nadu, India, during *Kuruvai* season (June – September 2023). The experimental site was situated at an altitude of +5.79 m MSL, 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 *viz.,* 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}) and replicated thrice. Fertilizers were applied as per the recommended dose of NPK (120:40:40 kg/ha). Study aimed 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.

Results and Discussion

Yield attributes and yield of rice

The yield attributes *viz.,* number of panicles m^{-2}, number of filled grains panicle^{-1}, panicle length and test weight 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 uptake results in more dry matter buildup and transport to the sink. The effective assimilate translocation to the sink might have resulted in sound grain filling, as evidenced by the highest number of filled grains panicles^{-1}. The increasing fertility levels led to higher grain yields. Maximum grain yield was achieved with an 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 in turn 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 resulted in better development of yield components. Similar results were reported by Kumar *et al*. (2017) and Maisnam and Tiwana (2021). The 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 confirmed 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 improved photosynthetic efficiency and reproductive sink ability to use incoming assimilates. These results are in agreement with the work of Anshuman and Rao (2021). 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).

Economics

The economic viability of crop cultivation is closely linked to the productivity of the crop, which in turn influences key economic attributes such as net returns and benefit-cost ratio (BCR). Despite the higher cost of cultivation associated with the application of 100% Recommended Dose of Fertilizers (RDF) with soil application of Zn-EDTA @ 5 kg ha^{-1} and foliar spray of nano Zn @ 0.2% during active tillering and panicle initiation stages has shown higher result of gross return (Rs. 120076), net return (Rs. 70381), and benefit cost ratio (2.42). This can be attributed to the significantly higher grain yield and straw yield achieved with this treatment. The increased yield not only offset the additional input costs but also resulted in substantially higher net income and BCR (Table.3)

Conclusion

The current study compared the impacts of several Zn application techniques on rice yield 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 while post-harvest nutrient status on land therefore, improve zinc use efficiency.

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)	Test weight (g)
T_1 – Control	236	71.36	12.35	15.10
T_2 - 100 % RDF	268	79.42	14.42	15.14
T_3 - 100% RDF + Soil application of $ZnSO_4$ @ 25kg ha^{-1}	298	84.54	15.24	15.20
T_4 - 100 % RDF + Soil application of Zn-EDTA @ 5kg ha^{-1}	348	92.14	16.20	15.22
T_5 - 100 % RDF + Foliar spray of ZnO_2 @ 0.5 %	324	88.76	15.64	15.25
T_6 - 100 % RDF + Foliar spray of nano Zn @ 0.2%	354	92.42	16.22	15.18
T_7 - 100% RDF + Soil application of $ZnSO_4$ @ 25 kg ha^{-1} + Foliar spray of ZnO_2 @ 0.5%	377	98.24	16.49	15.32
T_8 -100% RDF + Soil application of $ZnSO_4$ @ 25 kg ha^{-1} + Foliar spray of nano Zn @ 0.2%	398	101.82	16.82	15.36
T_9 - 100% RDF + Soil application of Zn-EDTA @ 5kg ha^{-1} + Foliar spray of ZnO_2 @ 0.5%	423	107.80	17.10	15.42
T_{10} - 100% RDF + Soil application of Zn-EDTA @ 5kg ha^{-1} + Foliar spray of nano Zn @ 0.2%	442	110.16	17.46	15.50
S. Ed±	4.3	1.40	0.31	0.28

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

Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
T_1 – Control	1757	2754
T_2 - 100 % RDF	3462	5604
T_3 - 100% RDF + Soil application of $ZnSO_4$ @ 25kg ha^{-1}	3755	5946
T_4 - 100 % RDF + Soil application of Zn-EDTA @ 5kg ha^{-1}	4286	6512
T_5 - 100 % RDF + Foliar spray of ZnO_2 @ 0.5 %	4045	6230
T_6 - 100 % RDF + Foliar spray of nano Zn @ 0.2%	4358	6602
T_7 - 100% RDF + Soil application of $ZnSO_4$ @ 25 kg ha^{-1} + Foliar spray of ZnO_2 @ 0.5%	4716	6912
T_8 -100% RDF + Soil application of $ZnSO_4$ @ 25 kg ha^{-1} + Foliar spray of nano Zn @ 0.2%	5051	7224
T_9 - 100% RDF + Soil application of Zn-EDTA @ 5kg ha^{-1} + Foliar spray of ZnO_2 @ 0.5%	5402	7646
T_{10} - 100% RDF + Soil application of Zn-EDTA @ 5kg ha^{-1} + Foliar spray of nano Zn @ 0.2%	5609	7896
S. Ed±	79.68	115.2
CD (p=0.05)	167	243

Table 3: Effect of different sources of zinc application on economics of rice cultivation

Treatments	Cost of cultivation (Rs. ha^{-1})	Gross income (Rs. ha^{-1})	Net income (Rs. ha^{-1})	BCR
T_1 – Control	34225	37894	3669	1.11
T_2 - 100 % RDF	47095	74844	27749	1.59
T_3 - 100% RDF + Soil application of $ZnSO_4$ @ 25kg ha^{-1}	48970	81046	32076	1.66
T_4 - 100 % RDF + Soil application of Zn-EDTA @ 5kg ha^{-1}	48095	92232	44137	1.92
T_5 - 100 % RDF + Foliar spray of ZnO_2 @ 0.5 %	47751	87130	39379	1.82
T_6 - 100 % RDF + Foliar spray of nano Zn @ 0.2%	48695	93762	45067	1.93
T_7 - 100% RDF + Soil application of $ZnSO_4$ @ 25 kg ha^{-1} + Foliar spray of ZnO_2 @ 0.5%	49626	101232	51606	2.04
T_8 -100% RDF + Soil application of $ZnSO_4$ @ 25 kg ha^{-1} + Foliar spray of nano Zn @ 0.2%	50570	108244	57674	2.14
T_9 - 100% RDF + Soil application of Zn-EDTA @ 5kg ha^{-1} + Foliar spray of ZnO_2 @ 0.5%	48751	115686	66935	2.37
T_{10} - 100% RDF + Soil application of Zn-EDTA @ 5kg ha^{-1} + Foliar spray of nano Zn 0.2%	49695	120076	70381	2.42

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