Effect of Different Zinc Fertilization Strategies on Growth, Yield, and Profitability of Transplanted or Direct-Seeded Rice

ABSTRACT

The research was conducted to determine how rice growth and productivity would be impacted using graded amounts of zinc fertilizer in rice variety ADT-43 at Annamalai University's Experimental Farm, Tamil Nadu, India. This investigation on the effect of different sources of zinc on growth and yield of transplanted rice was conducted during *kuruvai* season (June – September 2023). Different quantities of zinc fertilizers were employed in the ten treatments. Three independent studies of the treatments were carried out and the field trial was designed employing randomised block design (RBD). According to the research outcome, among the different treatments, 100% RDF + Soil application of Zn-EDTA @ 5kg ha^{-1} + Foliar spray of nano Zn @ 0.2% at active tillering and panicle initiation resulted in higher morphological characters, including plant height (124.11cm), leaf area index (4.84), dry mater production (13012 kg/ha), number of tillers/hill (33.30) and yield characteristics, including number of panciles m^{-2}, panicle length, number of filled grains $panicle^{-1}$ and test weight, grain yield (6693 kg/ha) and straw yield (7865 kg/ha) of rice. Several indicators pointed to reduced productivity and insufficient growth and development in the control treatment scenario. The study revealed that application of 100% RDF + Soil application of Zn-EDTA @ 5kg ha^{-1} + Foliar spray of nano Zn @ 0.2% at active tillering and panicle initiation could be considered a better for achieving the growth and yield attributes of ADT-43 under transplanted condition.

Keywords: Growth, rice, zinc sulphate, zinc oxide, nano zinc, 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 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 (Kumar et al., 2024). It is a component of protein, nucleic acid, and other molecules important for plant growth (Singh et al., 2024). 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.

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.

RESULTS AND DISCUSSION

Growth Attributes

The various growth characters of rice, such as plant height, leaf area index, dry matter production and number of tillers were significantly influenced by application of recommended dose of fertilizers (RDF) and zinc fertilizer (Table.1). The application 100% RDF + Soil application of Zn-EDTA @ 5kg ha^{-1} + Foliar spray of nano Zn @ 0.2% (T_{10}) recorded the higher plant height. The increase in growth attributes might be due to nitrogen is a major nutrient needed in large quantities and it is a constituent in nucleic acids, proteins, nucleotides, chlorophyll, chromosomes and enzymes. Phosphorus supports root formation, cell division, meristematic tissue development, and flowering. Potassium aids in amino acid synthesis, protein formation, nutrient uptake, and the development of bold grains. Similar observations were reported by kumar *et al*. (2017). chelated zinc might be the positive effect of zinc on root proliferation, results in increased nutrient uptake from the soil and supply to aerial parts of the plant and ultimately higher vegetative growth Similar results were also observed by Sudhagar *et al*. (2019). Nano zinc is known to affect plant height because it is involved in producing indole-acetic acid (IAA). This phytohormone promotes internode elongation, contributing to increased plant height. Similar findings were reported by Sahana *et al*. (2023). The higher LAI might be due to the availability and absorption of macronutrients from initial stages of the crop growth from the soil or through foliar feeding favoured the crop growth. Similar observations were reported by Bastola *et al*. (2021). Increased dry matter production might be due to adequate availability of nutrients from NPK combined with Zinc-EDTA and nano zinc. This combination supports balanced nutrient availability during crop growth. Enhanced nutrient availability, especially zinc, under aerobic conditions likely boosts photosynthate buildup as dry matter. Nano zinc application increases leaf zinc accumulation and amino acid reduction, which, along with increased protein content, serves as a substrate for dry matter formation. Similar results were also observed by Theerthana *et al*. (2022). The maximum number of tillers hill^{-1} was also increased this could be due to the presence of macronutrients in the soil from initial stages of the crop growth and supplemental addition of micro-nutrient nourished the crop very well, enhanced the metabolic activity of the plants and resulted in more number of tillers. Similar findings were reported by Sonboir *et al*. (2020).

Yield

The yield potential of the rice crop is determined by the values of growth and yield attributes (Table.2). Among the different treatments, application of 100 % RDF + soil application of Zn-EDTA @ 5 kg ha^{-1}+ foliar spray of Nano zinc @ 0.2% (T_{10}) 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. 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 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 Kumar *et al*. (2022).

CONCLUSION

From this present study, the results showed that there was a marked variation in the productivity of rice to different sources of zinc. The conjoint application of 100% RDF + Soil application of Zn EDTA @ 5kg ha^{-1} + Foliar spray of nano Zn @ 0.2 % was the optimal nutrient management practices to boost the production and productivity and as well as profitability of rice. Therefore, it can be recommended that farmers in the Cauvery delta region of Tamil Nadu implement this nutrient management approach.

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TREATMENTS	**Plant height (cm)**	**Leaf area index (cm)**	**Dry matter production (kg ha^{-1})**	**Number of tillers hill^{-1}**
T_1 – Control	72.12	3.61	4059	6.51
T_2 - 100 % RDF	75.03	3.90	8159	7.12
T_3 - 100% RDF + Soil application of $ZnSO_4$ @ 25kg ha^{-1}	78.50	4.16	8730	7.64
T_4 - 100 % RDF + Soil application of Zn-EDTA @ 5kg ha^{-1}	86.10	4.72	9738	8.45
T_5 - 100 % RDF + Foliar spray of ZnO_2 @ 0.5 %	82.60	4.38	9247	8.02
T_6 - 100 % RDF + Foliar spray of nano Zn @ 0.2%	88.63	4.74	9824	8.64
T_7 - 100% RDF + Soil application of $ZnSO_4$ @ 25 kg ha^{-1} + Foliar spray of ZnO_2 @ 0.5%	93.13	4.96	10465	9.04
T_8 -100% RDF + Soil application of $ZnSO_4$ @ 25 kg ha^{-1} + Foliar spray of nano Zn @ 0.2%	96.94	5.14	11047	9.62
T_9 - 100% RDF + Soil application of Zn-EDTA @ 5kg ha^{-1} + Foliar spray of ZnO_2 @ 0.5%	100.76	5.39	11743	10SS.24
T_{10} - 100% RDF + Soil application of Zn-EDTA @ 5kg ha^{-1} + Foliar spray of nano Zn @ 0.2%	104.56	5.64	12154	10.64
S. Ed±	1.27	0.09	152	0.17
CD (p=0.05)	2.69	0.19	320	0.36

Table.1. Effect of zinc sources on plant height, leaf area index, dry matter production and at harvest stage and number of tillers /hill at active tillering stage of rice

Table.2. Effect of zinc sources on grain yield, straw yield and harvest index of rice

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
T_7 - 100% RDF + Soil application of $ZnSO_4$ @ 25 kg ha^{-1} + Foliar spray of ZnO_2 @ 0.5%	4716	6912	40.56
T_8 -100% RDF + Soil application of $ZnSO_4$ @ 25 kg ha^{-1} + Foliar spray of nano Zn @ 0.2%	5051	7224	41.15
T_9 - 100% RDF + Soil application of Zn-EDTA @ 5kg ha^{-1} + Foliar spray of ZnO_2 @ 0.5%	5402	7646	41.40
T_{10} - 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