Impact of Foliar Application of Nano Nitrogen, Zinc and Copper on Yield and Nutrient Uptake of Rice

ABSTRACT

A field experiment was conducted during *rabi* 2020-21 at Wetland farms of Tamil Nadu Agricultural University, Coimbatore to study the effect of foliar nanonutrients (N, Zn and Cu) application on the yield and nutrient uptake by rice at harvest. Twelve treatments with three replications were laid out in randomized complete block design. The results revealed that application of 100% NPK + Nano N at active tillering (T_3) and 75% N + 100% PK + Nano N at active tillering (T_4) increased the grain yield (5112 and 5063 kg ha^{-1}) and N uptake (106.48 and 89.51 kg ha^{-1}) of rice, respectively and was on par with 100% NPK + Nano Zn at active tillering and panicle emergence (T_{10}). However, significantly higher Zn and Cu uptake were recorded in 100% NPK + Nano Zn at active tillering and panicle emergence (T_{10}, 457.61 g ha^{-1}) and 100% NPK + Nano Cu at active tillering and panicle emergence (T_{12}, 92.36 g ha^{-1}), respectively which was followed by 100% NPK + Nano N at active tillering (T_3, 372.45 and 81.51 g ha^{-1}) and 75% N + 100% PK + Nano N at active tillering (T_4, 355.41 and 84.13 g ha^{-1}). Thus, it can be concluded that application of foliar nano N at active tillering along with soil application of either 100% NPK or 75% N + 100% PK can provide better results in terms of grain yield and nutrient uptake.

Keywords: Nano nitrogen; nano zinc; nano copper; foliar application; rice; yield

1. INTRODUCTION

Rice (*Oryza sativa* L) is the major staple food for a large part of the world, especially in Asia. India is the world's second largest producers of rice accounting for 20% of all world rice production after China. Fertilizers play a major role in achieving such higher productivity and the fertilizer requirement for cereal crops is higher when compared to other crops for its growth, development and grain production [1]. Among various nutrients, nitrogen (N) is the key element for plants and its availability is the major factor determining crop growth and crop production. Most of the rice soils are deficient in N, yet the efficiency of added conventional fertilizer N in rice is around 30-45% [2]. This low N use efficiency in rice culture is attributed mainly to denitrification, ammonia volatilization and leaching losses. This necessitates to develop new fertilizers in combination with soil application to enhance N availability during the crop period.

After nitrogen, zinc (Zn) is the most important nutrient that limits the grain yield of rice and is a global concern for human nutrition. Zn acts as a cofactor of antioxidant enzymes such as catalase and peroxidase, plays an important part in plant protection and ultimately improves yield. Zinc has an important role in several physiological processes of the plants such as protein synthesis, enzyme activation, gene expression and carbohydrate metabolism. Studies have shown that zinc improves the absorption of other nutrients such as potassium, phosphorus and iron for the plant [3]. The efficiency of applied zinc sulphate ($ZnSO_4$) is only 1 to 4% and most of the applied zinc is rendered unavailable to plants due to many factors such as leaching, fixation [4]. Copper (Cu) is also one of the essential microelements that plays an important role in the metabolism of N and Zn compounds [5]. However, Cu deficiency can harm plant metabolism, resulting in low crop yield and physiological disturbance and excess can be highly toxic [6]. Hence it is essential to balance the fertilizer application, minimize the nutrient losses, improve its efficiency and increase the crop yield through exploitation of new applications with the help of nano-technology and nanomaterials.

Nano fertilizers have unique physico-chemical properties and the potential to boost the plant metabolism. Nanoscale materials can enhance the fertilizer use efficiency and especially, foliar application can meet the crop nutrient requirement effectively as per its need. Nano foliar fertilizers are more reactive that can penetrate through the epidermis allowing for gradual release and targeted distribution, thus increasing the nutrient uptake and enhancing nutrient use efficiency. Nano foliar fertilizers also aid in preventing environmental pollution by reducing soil and water pollution and could be called as new fertilizer alternatives [7]. Thus, fertilizing the crop combined with reduced soil application saves the farming systems from the inherent challenges posed by low or declining nutrient use efficiencies. Keeping in view of the above points, this study was framed to assess the impact of foliar nanonutrients application on the yield and nutrient uptake of transplanted rice.

2. MATERIAL AND METHODS

A field experiment was conducted during *rabi* 2020-21 (December to April) at Tamil Nadu Agricultural University, Coimbatore which is located at 11˚N latitude and 77˚E longitude, at an altitude of 426.7 m above mean sea level. The soil of the experimental site is clay loam in texture and slightly alkaline in reaction (pH of 8.1). Initial organic carbon status of the soil was medium (0.60%) with low in available nitrogen (212 kg ha^{-1}), medium in available phosphorus (11.58 kg ha^{-1}), high in available potassium (686 kg ha^{-1}), high in both available zinc (10.3 mg kg^{-1}) and available copper (9.5 mg kg^{-1}).

The experiment comprises of twelve treatments and three replications laid in randomized complete block design. The treatments are: T_1 - 100% NPK, T_2 - 0% N + 100% PK, T_3 - 100% NPK + Nano N at AT (active tillering), T_4 - 75% RD N + 100% PK + Nano N at AT, T_5 - 50% RD N + 100% PK + Nano N at AT, T_6 - 100% NPK + Nano N + Nano Cu + Nano Zn at AT, T_7 - 75% RD N + 100% PK + Nano N + Nano Cu + Nano Zn at AT, T_8 - 50% RD N + 100% PK + Nano N + Nano Cu + Nano Zn at AT, T_9 - 100% NPK + Nano Zn at AT, T_{10} – 100% NPK + Nano Zn at AT and PE (panicle emergence), T_{11} - 100% NPK + Nano Cu at AT, T_{12} - 100% NPK + Nano Zn at AT and PE. The gross plot size of each treatment was 5 m × 4 m (20 m^2).

Rice variety CO 51, was used for nursery raising and main field transplanting. SRI method of rice cultivation was followed. All the other cultivation practices were followed as per [8] of Tamil Nadu Agricultural University. The recommended dose of fertilizer is 150:50:50 kg NPK ha^{-1}. The entire recommended dose of N and K were applied to soil in three equal splits *i.e.*, at basal, active tillering and panicle initiation stage whereas the total phosphorus (P) was applied as basal. Nano N, Zn and Cu were applied as foliar at the rate of 8 ml l^{-1} of water. First foliar spray was done on 30 DAT and second spray was done on 60 DAT as per the scheduled treatments. The liquid nano N, Zn and Cu contained 40000 ppm of N, 10000 ppm of Zn and 8000 ppm of Cu.

The gross plot and net plot area of each treatment were harvested separately with the help of sickle. The harvested plants from each net plot were threshed, sun dried, winnowed separately and weight of the grain and straw of each treatment was recorded as kg $plot^{-1}$ and was converted into kg ha^{-1}. Plant samples at harvest from each plot were collected and oven dried at 70℃. The samples were grounded into fine powder using Willey mill and analysed for N, P, K, Zn and Cu content using standard procedures. The total uptake by the plant (grain + straw) was calculated using the formula:

$$\text{Macronutrient uptake (kg ha}^{-1}) = \text{Macronutrient content (\%)}/100 \times \text{Yield (kg ha}^{-1})$$

$$\text{Micronutrient uptake (g ha}^{-1}) = \text{Micronutrient content (mg kg}^{-1})/1000 \times \text{Yield (kg ha}^{-1})$$

Table 1. Methods employed for plant nutrient analysis

Nutrient	Method employed
Total Nitrogen	Micro kjeldahl method [9]
Total Zinc	Tri-acid extract using atomic absorption spectrophotometer at 213.86 nm [10]
Total Copper	Tri-acid extract using atomic absorption spectrophotometer at 324.75 nm [10]

The data recorded was statistically analysed using analysis of variance (ANOVA) technique at 5% probability level as described by [11] to draw valid conclusions.

3. RESULTS AND DISCUSSION

3.1 Grain and Straw yield

The grain and straw yield of rice were significantly influenced by different levels of soil nitrogen in combination with foliar application of nano N, Zn and Cu (Table 2). The highest grain yield of 5112 kg ha^{-1} was recorded with the application of 100% NPK + Nano N at active tillering (T_3) which was on par with 75% N + 100% PK + Nano N at active tillering (T_4) and 100% NPK + Nano Zn at active tillering and panicle emergence (T_{10}) and significantly higher over rest of the treatments. This might be due to the synergetic effect of nano nitrogen through foliar penetration of nutrients and conventional urea through roots uptake that improved nitrogen uptake by the plant leading to improved photosynthesis

[12], thus resulting in increased source and sink capacity [13]. Foliar application of three nano nutrients (N, Zn and Cu) in combination with 100% NPK (T_6) recorded higher grain yield which was on par with single foliar spray of either Zn or Cu as well as 100% NPK alone. This implies that there is antagonistic or zero interaction between Zn and Cu when mixed and sprayed at higher doses [14]. The lowest grain yield (3491 kg ha^{-1}) was observed in the treatment with no nitrogen and 100% PK (T_2).

The dry matter accumulation is crucial for obtaining higher grain yields [15]. With regard to straw yield, there was significant influence of nano nutrients foliar application (Table 2). The highest straw yield (10943 kg ha^{-1}) was observed with 100% NPK + Nano N at active tillering (T_3) which was on par with 100% NPK + Nano Zn at active tillering (T_9, 10928 kg ha^{-1}) and 100% NPK alone (T_1, 10558 kg ha^{-1}) and significantly higher over the rest of the treatments. Increase in the straw yield with the foliar application of nano N and nano Zn fertilizers is due to the quick absorption of nano fertilizers by the plant that increased photosynthetic rate and dry matter production which in turn resulted in higher straw yield. These results are in agreement with the findings of [12] in rice. The treatment with no nitrogen and 100% PK (T_2) recorded the lowest straw yield (7945 kg ha^{-1}).

3.2 Nitrogen Uptake

The foliar application of nanonutrients (N, Zn and Cu) showed significant effect on the total uptake of N, P, K, Zn and Cu by rice plant at harvest (Table 3). Significantly higher total nitrogen uptake at harvest (106.48 kg ha^{-1}) was observed with the application of 100% NPK + Nano N at active tillering (T_3) which was followed by 100% NPK + Nano Zn at active tillering and panicle emergence (T_{10}, 96.86 kg ha^{-1}) and 75% RDN + 100% PK + Nano N at active tillering (T_4, 89.51 kg ha^{-1}). This might be due to the foliar application of nano N that caused rapid absorption due to lesser particle size than the pore size of the leaves and transport of nano nutrients within the plant [16].

The nitrogen uptake in the treatment receiving 100% NPK + Nano NZnCu at active tillering (T_6, 83.43 kg ha^{-1}) was significantly lower when compared with either nano N (T_3) or nano Zn alone (T_9). This might be due to the production of reactive oxygen species (ROS) following higher rate of application of copper that decreased nitrate and nitrite reductase activity in plants [17], which in turn hindered the nitrogen uptake. Also, excess Cu inhibits the photosynthetic activity [18] and synthesis of proteins. The lowest nitrogen uptake (54.23 kg ha^{-1}) was observed in T_2 with no nitrogen and 100% PK.

3.3 Zinc Uptake

Significantly higher total zinc uptake by plants at harvest (Table 3) was recorded with application of 100% NPK + Nano Zn at active tillering and panicle emergence (T_{10}, 457.61 g ha^{-1}). Application of foliar nano Zn twice during the crop growth period increased the Zn uptake by the plant significantly. These results were in confirmation with the findings of [2]. However, 100% NPK + Nano Zn at active tillering (T_9, 403.94 g ha^{-1}) and 100% NPK + Nano NZnCu at active tillering (T_6, 383.48 g ha^{-1}) were on par with each other. This shows that combined application of three nano nutrients increased Zn uptake but hindered Cu uptake by the plant. This might be due to the fact that both Zn and Cu are absorbed by the plant in the form of cations which possess similar transporters to enter into the plant that causes reduction in the uptake of either of the ions [19]. Application of 100% NPK + nano Cu twice at active tillering and panicle emergence (T_{12}, 331.83 g ha^{-1}) significantly reduced the Zn uptake when compared to 100% NPK + foliar nano Cu at active tillering alone (T_{11}, 369.28 g ha^{-1}). This explains that increase in Cu application at higher rate reduces the Zn uptake.

3.4 Copper Uptake

The foliar application of nano Cu twice at active tillering and panicle emergence along with 100% NPK (T_{12}, 92.36 g ha^{-1}) recorded significantly higher Cu uptake (Table 3). However, 100% NPK + Nano Cu at active tillering (T_{11}, 85.87 g ha^{-1}), 75% N + 100% PK + Nano N at active tillering (T_4, 84.13 g ha^{-1}) and 100% NPK + Nano N at active tillering (T_3, 81.51 g ha^{-1}) were on par with each other. This is due to addition of N that caused increase in the micronutrient uptake. Application of 100% NPK + Nano NZnCu at active tillering (T_6) recorded lower Cu uptake of 66.34 g ha^{-1}. This is due to sufficient Zn availability in the plant and the antagonistic effect of Zn and Cu at higher rates of application reduced the Cu uptake and increased Zn uptake [20].

Table 2. Effect of foliar nanonutrients (N, Zn and Cu) application on the grain and straw yield of rice

Treatment	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})
T_1 (100_{NPK})	4399	10558
T_2 (0_N +100_{PK})	3491	7945
T_3 (100_{NPK} + nFN @ AT)	5112	10943
T_4 (75_N + 100_{PK} + nFN @ AT)	5063	9022
T_5 (50_N + 100_{PK} + nFN @ AT)	4332	8220
T_6 (100_{NPK} + nFNZnCu @ AT)	4635	9373
T_7 (75_N + 100_{PK} + nFNZnCu @ AT)	4455	8120
T_8 (50_N + 100_{PK} + nFNZnCu @ AT)	4025	9192
T_9 (100_{NPK} + nFZn @ AT)	4598	10928
T_{10} (100_{NPK} + nFZn @ AT & PE)	4737	8924
T_{11} (100_{NPK} + nFCu @ AT)	4297	9326
T_{12} (100_{NPK} + nFCu @ AT & PE)	4209	9280
SEd	214	419
CD (P = 0.05)	440	850

nFN: Nano Foliar Nitrogen, nFNZnCu: Nano Foliar Nitrogen + Zinc + Copper, nFZn: Nano Foliar Zinc, nFCu: Nano Foliar Copper, AT: Active Tillering, PE: Panicle emergence

Table 3. Effect of foliar nanonutrients (N, Zn and Cu) application on micronutrient (Zn and Cu) uptake by plant at harvest

nFN: Nano Foliar Nitrogen, nFNZnCu: Nano Foliar Nitrogen + Zinc + Copper, nFZn: Nano Foliar Zinc, nFCu: Nano Foliar Copper, AT: Active Tillering, PE: Panicle emergence

4. CONCLUSION

Application of either 100% NPK + Nano N at active tillering or 75% N + 100% PK + Nano N at active tillering had resulted in higher grain yield and nitrogen, zinc and copper uptake by rice which was on par with 100% NPK + Nnao Zn at active tillering and panicle emergence.

Treatment	N uptake (kg ha^{-1})	Zn uptake (g ha^{-1})	Cu uptake (g ha^{-1})
T_1 (100_{NPK})	86.42	342.31	67.02
T_2 (0_N +100_{PK})	54.23	269.82	37.96
T_3 (100_{NPK} + nFN @ AT)	106.48	372.45	81.51
T_4 (75_N + 100_{PK} + nFN @ AT)	89.51	355.41	84.13
T_5 (50_N + 100_{PK} + nFN @ AT)	76.01	291.97	66.09
T_6 (100_{NPK} + nFNZnCu @ AT)	83.43	383.48	66.34
T_7 (75_N + 100_{PK} + nFNZnCu @ AT)	70.72	284.57	56.90
T_8 (50_N + 100_{PK} + nFNZnCu @ AT)	59.23	307.09	61.26
T_9 (100_{NPK} + nFZn @ AT)	86.11	403.94	58.92
T_{10} (100_{NPK} + nFZn @ AT & PE)	96.86	457.61	63.70
T_{11} (100_{NPK} + nFCu @ AT)	80.87	369.28	85.87
T_{12} (100_{NPK} + nFCu @ AT & PE)	82.76	331.83	92.36
SEd	4.03	14.58	2.35
CD (P = 0.05)	8.35	31.39	5.94

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