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Sushil Kumar Kothari,
Dean, School of Agriculture and Allied Sciences (SAAS), The Neotia University, Sarisha, Jhinga, South 24 Parganas, West Bengal, India

Sruba Saha
Assistant Professor, Department of Genetics and Plant Breeding, School of Agriculture and Allied Sciences (SAAS), The Neotia University, Sarisha, Jhinga, South 24 Parganas, West Bengal, India

Parvez Mallick
Assistant Professor, Department of Agriculture Economics and Statistics, School of Agriculture and Allied Sciences (SAAS), The Neotia University, Sarisha, Jhinga, South 24 Parganas, West Bengal, India

Corresponding Author:
Sruba Saha
Assistant Professor, Department of Genetics and Plant Breeding, School of Agriculture and Allied Sciences (SAAS), The Neotia University, Sarisha, Jhinga, South 24 Parganas, West Bengal, India

Evaluation of foliar application of nano-fertilizers (nitrogen, zinc, copper) on growth and yield of rice (*Oryza sativa* L.) in *kharif* season

Sushil Kumar Kothari, Sruba Saha and Parvez Mallick

Abstract
A field experiment was conducted during Kharif season of 2020-21 at the research farm of School of Agriculture and Allied Sciences (SAAS), The Neotia University. The experiment consisted 5 treatments including basal application of NPK at 80: 40: 40 + broadcasting of N at 40 kg/ha (T_1-control) and replacing broadcasting of N with two-times foliar spray of nano nitrogen at 4 ml litter^{-1} (T_2-nano N), nano nitrogen & nano zinc (T_3-nano N & Zn), nano nitrogen & nano copper (T_4-nano N & Cu) and nano nitrogen, nano zinc & nano copper (T_5-nano N, Zn & Cu) in Randomized Block Design with 3 replications. The results of experimental revealed that the rice grain yield significantly increased by 8-12% with T_3 – nano N & Zn, T_5-nano N, Zn & Cu, T_4-nano N & Cu and T_2-nano N over T_1-control. The differences in yield amongst the treatments T_2, T_3, T_4 and T_5, however, were not significantly different indicating no significant advantage of nano Zn and nano Cu applications. Based on all of the studied yield attributing & yield characters it was concluded that two-times foliar application of nano N has significant advantages over broadcasting of N at 40 kg/ha. These results, however, needs further confirmation through conducting multi-locational long term trials supported by nutrient like N, Zn and Cu uptake data in view of significant advantages of nano N fertilizer over traditional N fertilizers like urea, ammonium sulphate, etc.

Keywords: Nitrogen, nano nitrogen, nano zinc, nano cupper, nano fertilizers, rice

Introduction
Rice is one of the most important cereal crops of the world. Presently more than 90% of total rice production and consumption in Asia. India is the world's second largest producers of rice accounting for 22% of all world rice production after China. In India, rice occupied almost 70% of the total agricultural crop areas of the state during 2013-14 and it contributed the same percentage (71%) towards the total production of all agricultural crops during the same period (Annual report, 2019 – 20) [1] West Bengal is one of the important agricultural state in eastern Indian in spite of having only 2.78 per cent of total country's cultivable area. In West Bengal, the production of rice was 14.80 million tonnes during the period 2014-15, which was about 14.03 Percent of the country production, which was the major contribution (Anonymous, 2016) [2]. Fertilizers play a major role to achieving such higher production and productivity. The fertilizer requirement for cereal crops is higher when compared to other crops for its growth, development and grain production (Sahrawat *et al*. 2000) [3]. In India, most of the rice soils are deficient in Nitrogen (N) that is why during past few decades, rice production increased mostly due to adoption of high yielding nitrogen responsive rice varieties including increase in irrigated area and use of chemical fertilizers. Low N use efficiency in rice culture is attributed mainly to denitrification, ammonia volatilization and leaching losses. Zinc (Zn) is considered second most important yield limiting nutrient after nitrogen. The critical limit of available zinc in the soil suitable for rice growth is 0.3 mg kg^{-1}. The plant available zinc in Indian soils extracted with DTPA is less than 1% of total zinc (Takkar and Mann, 1975) [4].
Arnon and Stout (1939) [5] proposed that, Cu is an essential element for plant growth. Among the micronutrients, Cu plays an important role in the crop growth by increasing the tillering and pollen viability of the crop (Das, 2014) [6]. From the above information it is clear that, new applications like nano-technology and nano-particles should be used to increase rice yield by reducing nutrient losses in fertilizer application. Nano fertilizers have unique physicochemical properties and the potential to boost the plant metabolism (Giraldo *et al*. 2014) [7]. The nano-fertilizers or nano encapsulated nutrients might have the properties that are effective to crops,

release the nutrients on demand, controlled release of chemical fertilizers that regulate the plant growth and enhanced target activity (DeRosa *et al*. 2010) [8]. Moreover, development of new fertilizers in combination (zinc, copper and nitrogen) both in chemical and bio forms to soil and foliar application is essential to enhance the production of rice, though very little information exists in previous research. Therefore, the present investigation was conducted to assess the impact of foliar Nano fertilizers and their combinations application on the yield and growth of transplanted rice.

Materials and Methods

The study was conducted at the research farm of School of Agriculture and Allied Sciences (SAAS), The Neotia University (22.261954°N latitude and 88.196574°E longitudes). The soil pH is 7.4 and EC of experimental area 4.2 ds $m^{-}1$. A well popular rice variety Shreya was sown Randomized Block Design (RBD) with 3 replications in *kharif* season, 2021. The experiment comprised 5 treatments including basal application of NPK at 80: 40: 40 + broadcasting of N at 40 kg/ha (T_1-control) and replacing broadcasting of N with two-times foliar spray of nano nitrogen at 4 ml $litter^{-1}$ (T_2-nano N), nano nitrogen & nano zinc (T_3-nano N & Zn), nano nitrogen & nano copper (T_4-nano N & Cu) and nano nitrogen, nano zinc & nano copper (T_5-nano N, Zn & Cu. Each treatment was foliar sprayed with 4 ml/litre water. The plot size of each treatment was 77 sq.mt and row distance and plant to plant distance were 20 and 6 cm, respectively. Data were taken on plant height (cm), No. tiller $plant^{-1}$, length of panicle (cm), no. of grain $panicle^{-1}$, test weight, yield $plot^{-1,}$ yield (quintal $hecter^{-1}$).

Results and Discussion

The results of analysis of variance showed a highly significant difference (p<0.01) among the applied treatments for all studied characters. Effect of the foliar application with different combination of nano-fertilizers were studied (Table 1).

Plant Height

Significantly highest grain yield was recorded with T_3 (nano nitrogen + nano zinc): 130.40 cm which was at par with T_5 (Nano nitrogen + nano zinc + nano copper): 128.37 cm and T_4 (nano nitrogen): 125.06 cm The lowest grain yield was registered under T1 (Control). (Table 1 and Figure 1) Related study by Liu and Lal (2014) [9] revealed similar findings in soybean. Similar results were also reported by Hemlatha *et al*. (2020) [10] in rice.

No. of tiller $plant^{-1}$

Foliar application of nano N along with and nano Zn showed better performance (28.7) followed by nano nitrogen + nano zinc + nano copper (T_5) *i.e*. 28.0 (Table 1 and Figure 1) compared to other treatments to growth parameters like no. of tillers $plant^{-1}$. Foliar application of these combined nano-fertilizers caused increase in the nitrogen uptake through leaves and roots that might have led to increased mobilization of synthesized carbohydrates into amino acid and protein which stimulated the rapid cell division and cell elongation (Song *et al*. 2013) [11]. Similar findings were observed in rice by Rathnayaka *et al*. (2018) [12] and in maize by Manikandan and Subramanian (2016) [13].

Length of panicle (cm)

The length of panicle was highest in treatment T_3 i.e., nano nitrogen + nano zinc (28.60 cm) which was at par with T_4 nano nitrogen + nano copper 26.67 cm (Table 1 and Figure 1). Similar pattern was observed with 100% NPK + Nano N at active tillering and panicle length treatment by Chandana *et al*. 2021 [14]. Significantly lower length of panicle was observed with nano nitrogen + nano zinc + nano copper (T_5) 21.97 cm. The result is strongly agreed with Sangra *et al*. 2018 [15].

No. of grains $panicle^{-1}$

No. of grains $panicle^{-1}$ recorded significantly highest for T_3 (nano nitrogen + nano zinc) 228.67 followed by T_5 (nano nitrogen + nano zinc + nano copper) 223.42 and T_4 (nano nitrogen + nano copper) 205.41 (Table 1 and Figure 1). Keram *et al*. (2012) [16] reported that the higher grain $panicle^{-1}$ with zinc and copper fertilizer application might be due to the fact that zinc plays an important role in biosynthesis of IAA and initiation of primordial for reproductive part which have favoured the metabolic reaction within plant.

Test weight (gm)

Maximum test weight was recorded in T_3 (nano nitrogen + nano zinc) 1.38 gm followed by T_5 (nano nitrogen + nano zinc + nano copper) 1.27 gm (Table 1 and Figure 1). Zinc Nano fertilizers with nano nitrogen was found to continuous increase in dry matter, total fresh and dry mass of root and shoot of rice crop and also effect of test weight. Highest rate being shown with increasing level of zinc nanofertilizers, which might be recognized to improved responses of antioxidant in rice crop treated with zinc nanofertilizers (Yomso *et al*. 2021) [17].

Yield (t/ha)

Yield (t/ha) significantly increased in T_3 (3.47 ton) followed by T_4 (3.43 ton) (Table 1 and Figure 1) whereas lowest yield wax recorded by control *i.e.* T_1. A peer of scientist revealed that nanofertilizers combined with nano zinc and nano nitrogen remarkably impact the straw and grain yield of rice (Janmohammadi *et al*, 2016) [18] and (Keram *et al*. 2012) [16]. Several other researchers also proved that the importance of nanofertilizers which actually increased of higher grain yield in rice by means of applying nano nitrogen combined with nano zinc (Apoorva *et al*. 2017) [19]. This is in concurrence with the results of detailing that nanofertilizers application expanded yield of crop by 20% - 40%. The overall study follows the similar trend which revealed that T_3 *i.e* nano nitrogen combined with nano zinc is the best treatment followed by T_5 (Nano nitrogen + nano zinc + nano copper) and T_2 (nano nitrogen) among the applied treatment.

Table 1: Effect of foliar application with Nano-fertilizers on yield and yield attributing traits of rice.

Treatment	Plant height (cm)	No. of Tiller plant^{-1}	Length of panicle (cm)	No. of grains panicle^{-1}	Test weight (gm)	Yield (t/ha)
T_1	122.56	12.60	23.87	185.56	1.22	3.09
T_2	123.80	18.0	22.73	192.53	1.26	3.40
T_3	130.40	28.7	28.60	228.67	1.38	3.47
T_4	125.06	22.7	26.67	205.41	1.26	3.43
T_5	128.37	28.0	26.52	223.42	1.27	3.33
SE	3.30	0.30	1.68	6.46	0.06	0.09
CD (0.05%)	6.59	0.59	3.35	18.24	0.12	0.19

T_1: Control (basal 100% NPK 80: 40: 40)
T_2: Basal + nano nitrogen (4 ml litter^{-1})
T_3: Basal + nano nitrogen + nano zinc (4 ml litter^{-1})
T_4: Basal + nano nitrogen + nano copper (4 ml litter^{-1})
T_5: Basal + nano nitrogen + nano zinc + nano copper (4 ml litter^{-1})

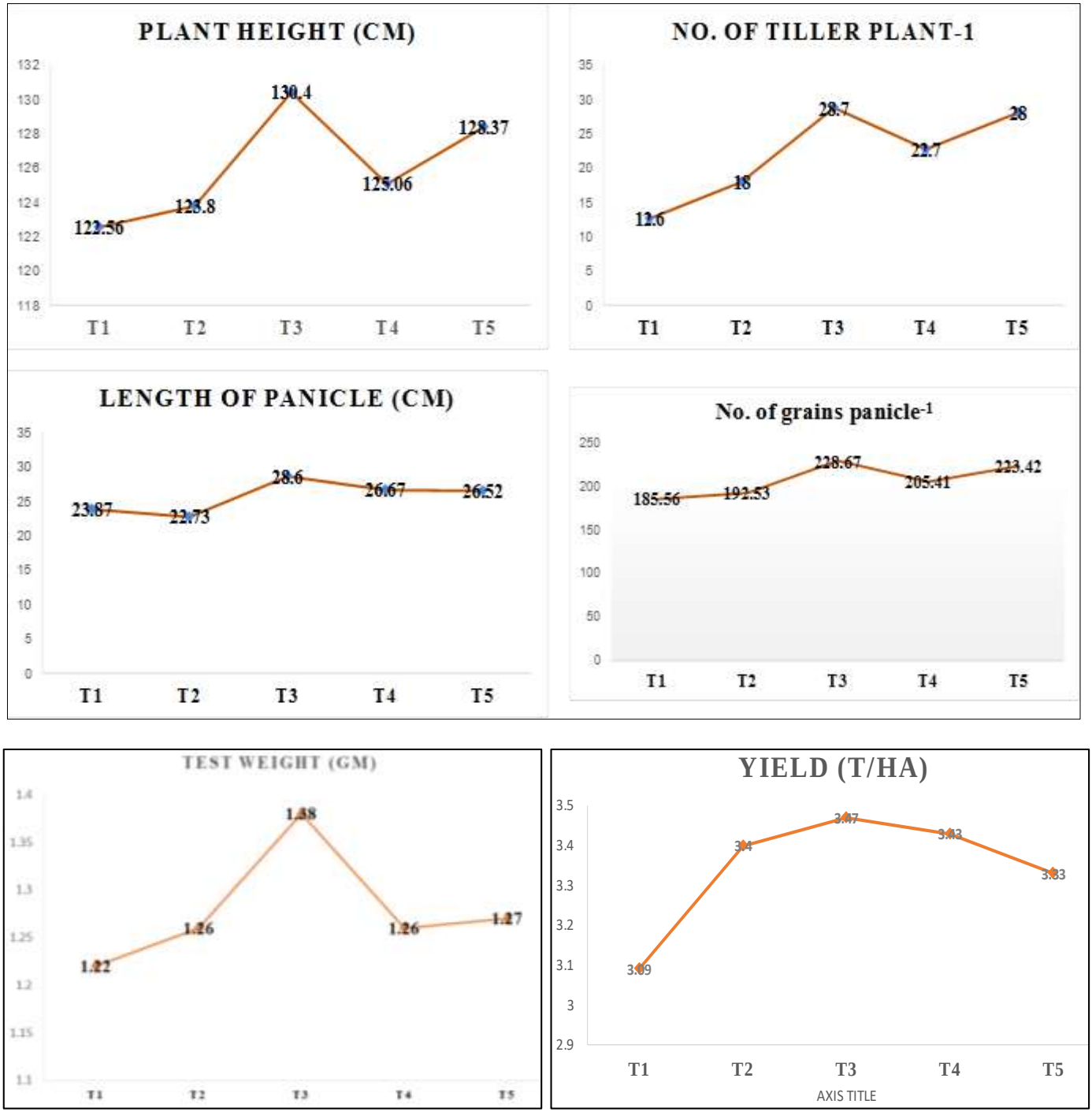

Fig 1: Different response of foliar application with Nano-fertilizers on yield and yield attributing traits of rice in graphical representation

Conclusion

Application of nanotechnology in agriculture is still in its budding stage. However, it has the potential to revolutionize agricultural systems particularly where the issues on fertilizer applications are concerned. Rice growth, development, and antioxidant activity were all boosted by nanofertilizer application specially with nano zinc along with nano nitrogen, which has the potential to improve crop production and plant nutrition specially in rice. The outcome of this research would also be beneficial for other studies involving the application of nanotechnology in the field of agriculture.

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