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Efficiency of Foliar Applied Nanonutrients (Nitrogen, Zinc and Copper) on Growth and Yield of Rice at Harvest

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ABSTRACT: A field experiment was conducted during *rabi* 2020-21 at the Wetland farms of Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore to study the effect of foliar nanonutrients (N, Zn and Cu) application on the growth and grain yield at harvest of transplanted rice. 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 showed highest plant height (88.93 cm), leaf area (38.98 cm^2), number of leaves (90.64) and drymatter production (105.32 g plant^{-1}) at harvest of rice which was at par with 75% N + 100% PK + Nano N at active tillering (87.92 cm, 36.87 cm^2, 82.52, 101.54 g plant^{-1}) and 100% NPK + Nano Zn at active tillering and panicle emergence (87.65 cm, 36.43 cm^2, 77.38, 98.42 g plant^{-1}). The highest number of total tillers hill^{-1}, productive tillers hill^{-1} at harvest and grain yield was recorded with the application of 100% NPK + Nano N at active tillering (29.15, 24.54 and 0.511 kg m^{-2}) which was at par with 75% N + 100% PK + Nano N at active tillering (27.67, 23.81 and 0.506 kg m^{-2}) and 100% NPK + Nano Zn at active tillering and panicle emergence (28.17, 23.42 and 0.474 kg m^{-2}), respectively. 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 growth and grain yield of rice.

Keywords: Nano nitrogen; nano zinc; nano copper; foliar application; rice; tiller production.

INTRODUCTION

Increasing population calls for escalation in the food production and introduction of green revolution in 1970's enhanced higher growth in agriculture which mainly relied on short statured high yielding varieties responsive to inorganic fertilizers, especially rice. But today, plant foliar feeding is the major point of 2030 Agenda for Sustainable Development, including seventeen sustainable development goals (Mahmoodi *et al*., 2020). The consumption of chemical fertilizers in India has increased by around 20% in last six years, from 51.0 million tonnes in 2015-16 to 61.4 million tonnes in 2020-21 (Annual report, 2019-20). So, in order to reduce the dependency on soil chemical fertilizers and increase the food production, foliar feeding of nano fertilizers remains as the best option for enhancing yield, nutrient use efficiency and reducing soil and environmental related issues. Nano fertilizers applied at the exponential growth phase of the crop enhances rapid absorption by the leaves, yet slow release and since they are required in small amount, reduces fertilizer consumption and environmental pollution (Liu and Lal, 2015).

Rice yield depends majorly on nitrogen and application of nitrogen to soil in the form of urea under lowland conditions, results in losses such as volatilization, denitrification, leaching and runoff and reduces the availability of nitrogen for rice (Lemraski *et al*., 2017). Foliar application of nano nitrogen in combination with prilled urea to rice negotiates the negative effects of soil applied fertilizers and utilizes the positive effects of foliar nano nutrients without compromising on the production. Rice is a poor source of zinc, copper and other micronutrients (Fakharzadeh *et al*., 2020). Zinc (Zn) deficiency in staple foods is a major threat in combating malnutrition related health problems in many developing countries. After nitrogen, zinc is the second most yield-limiting nutrient in rice (Quijano-Guerta *et al*., 2002). Copper concentration in rice need to be checked properly as deficiency or excess would lead to malnutrition or toxicity, respectively. With consideration of the above points, the experiment was set up to study the impact of foliar application of nano nitrogen, zinc and copper on growth parameters, tiller productivity and grain yield of transplanted rice.

MATERIAL AND METHODS

A field study was undertaken during *rabi* 2020-21 at the Wetland Farms of Department of Agronomy, 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 consists of twelve treatments laid out in randomized complete block design with three replications. 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. Rice CO 51, was used as the test variety and SRI method of rice cultivation was followed. All the other cultivation practices were followed as per recommended practice (CPG, 2020). The recommended dose of fertilizer is 150:50:50 kg $N:P_2O_5:K_2O$ 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 supplied by IFFCO were applied as foliar at the rate of 8 ml l^{-1} of water. With respect to combination treatments (T_6 to T_8), all the nano liquid fertilizers were tank mixed. 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, respectively.

The biometric observations on plant height, leaf area, number of leaves, total number of tillers $hill^{-1}$, productive tillers $hill^{-1}$ and drymatter production at harvest were recorded from the tagged five plants in the net plot area of each treatment and averaged. Leaf area was calculated by multiplying leaf length and leaf breadth. The grain yield was recorded from one sq. m area of net plot. The data recorded was statistically analysed using analysis of variance (ANOVA) technique at 5% probability level as described by Gomez and Gomez (2010) to draw valid conclusions.

RESULTS AND DISCUSSION

A. Effect of foliar application of nano N, Zn and Cu on the growth parameters of rice at harvest

The growth parameters such as plant height, leaf area, number of leaves and drymatter production of rice at harvest was significantly influenced by the foliar application of nano N, Zn and Cu (Table 1). The plant height of rice at harvest showed very slight variation between the treatments. The highest plant height (88.93 cm) was observed 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, 87.92 cm) and 100% NPK + Nano Zn at active tillering and panicle emergence (T_{10}, 87.65 cm). The leaf area and number of leaves were highest in treatment T_3 *i.e.*, 100% NPK + Nano N at active tillering (38.98 cm^2 and 90.64) which was at par with 75% N + 100% PK + Nano N at active tillering (36.87 cm^2 and 82.52) and 100% NPK + Nano Zn at active tillering and panicle emergence (36.43 cm^2 and 77.38), respectively. Similar pattern was observed with drymatter production wherein the highest drymatter production of 105.32 g $plant^{-1}$ was recorded in 100% NPK + Nano N at active tillering treatment (T_3) which was on par with 75% N + 100% PK + Nano N at active tillering (T_4, 101.54 g $plant^{-1}$) and 100% NPK + Nano Zn at active tillering and panicle emergence (T_{10}, 98.42 g $plant^{-1}$). Significantly lower growth parameters was observed with no nitrogen application and 100% PK (T_2).

Table 1: Efficiency of foliar applied nanonutrients (nitrogen, zinc and copper) on growth parameters of rice at harvest.

Treatment	Plant height (cm)	Leaf area (cm^2)	No. of leaves	Drymatter production (g $plant^{-1}$)
T_1 (100_{NPK})	83.38	34.29	75.17	91.00
T_2 (0_N +100_{PK})	78.77	28.55	44.00	68.84
T_3 (100_{NPK} + nFN @ AT)	88.93	38.98	90.64	105.32
T_4 (75_N + 100_{PK} + nFN @ AT)	87.92	36.87	82.52	101.54
T_5 (50_N + 100_{PK} + nFN @ AT)	81.52	32.23	59.00	84.61
T_6 (100_{NPK} + nFNZnCu @ AT)	85.23	33.72	72.75	94.25
T_7 (75_N + 100_{PK} + nFNZnCu @ AT)	84.45	32.75	74.50	91.16
T_8 (50_N + 100_{PK} + nFNZnCu @ AT)	82.38	32.39	65.83	84.08
T_9 (100_{NPK} + nFZn @ AT)	87.43	34.34	73.50	97.08
T_{10} (100_{NPK} + nFZn @ AT & PE)	87.65	36.43	77.38	98.42
T_{11} (100_{NPK} + nFCu @ AT)	86.72	34.79	71.00	89.08
T_{12} (100_{NPK} + nFCu @ AT & PE)	86.96	33.95	65.50	88.75
SEd	1.17	1.44	4.12	4.73
CD (*P* = 0.05)	3.43	2.99	8.54	9.81

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

Foliar application of nano N along with soil application of either 100% N or 75% N and nano Zn showed better performance compared to 100% NPK alone with respect to growth parameters like plant height, leaf area, number of leaves and drymatter production. Foliar application of nano N along with soil application of conventional urea 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). Similar findings were observed in rice by Rathnayaka *et al*., (2018) and in maize by Manikandan and Subramanian (2016). Nitrogen also promotes absorption of other nutrients including potassium and phosphorus which lead to increased total plant growth. Application of nano Zn might have enhanced the auxin biosynthesis that can stimulate cell division and better absorption of minerals and thus increased the plant growth (El-Tohamy and El-Greadly, 2007). This suggests that nanofertilizer can either provide nutrients for the plant or aid in the transport or absorption of available nutrients resulting in better crop growth (Benzon *et al*., 2015). The rapid absorption, penetration and slow release of nano nutrients enable the plants to utilize nano-fertilizers readily and completely, leading to an increase in plants biomass (Khalid *et al*., 2021). Liu and Liao (2008) found that the activity of water after adding nano materials was increased and N, P and K were absorbed by the plants along with the absorbed water, thus the dry matter production was also increased. The higher nutrient use efficiency and significantly lesser nutrient losses of nano fertilizers lead to higher growth and productivity (Mishra *et al*., 2020). Plants supplied with adequate amount of major and minor nutrients produced more leaves and brought about greater accumulation of photosynthates, produced taller plant with higher leaf area and finally dry matter accumulation.

Tank mix application of three nano nutrients reduced the growth parameters which might be due to antagonistic interactions that lead to reduced photosynthesis and ultimately the plant growth. Similar findings were observed by Chaudhry *et al*., (1973) in rice and Chaudhry and Lonerag (1970) in wheat. Nano Cu application twice at active tillering and panicle emergence showed reduced growth parameters compared to single application at active tillering alone which clearly suggests that the higher doses of copper applications can be toxic to the plant that leads to reduced photosynthesis, leaf area and ultimately lesser drymatter production. These results are in confirmation with the findings of Yang *et al*., (2020) in which exposure of rice seedlings to elevated levels of nano Cu led to reduced enzymatic activities and SPAD values.

B. Effect of foliar application of nano N, Zn and Cu on the tiller productivity of rice at harvest

The total number of tillers and productive tillers hill^{-1} at harvest of rice was significantly influenced by the foliar application of nano N, Zn and Cu. The highest number of total tillers hill^{-1} was recorded with the application of 100% NPK + Nano N at active tillering (29.15) which was on par with 100% NPK + Nano Zn at active tillering and panicle emergence (T_{10}, 28.17) and 75% N + 100% PK + Nano N at active tillering (T_4, 27.67). The productive tillers hill^{-1} was highest with 100% NPK + Nano N at active tillering (24.54) which was on par with 75% N + 100% PK + Nano N at active tillering (T_4, 23.81) and 100% NPK + Nano Zn at active tillering and panicle emergence (T_{10}, 23.42).

Tiller production in rice plant has direct relationship with the yield of crop (Panja *et al*., 2017). Vigorous tillering was observed in T_3 treatment due to more leaf area i.e., more active photosynthetic surface which ultimately facilitated higher number of tillers hill^{-1}. Increase in total number of tillers by nano N application may be because nitrogen might have influenced gibberellin hormone indirectly through cytokinin production (Jalali-Moridami and Ammiri, 2014). Nano Zn application caused increase in total number of tillers which may be attributed to its role in various Zn induced enzymatic activity and auxin metabolism which control growth of plant (Ghani *et al*., 1990). Total number of tillers unit area^{-1} is the base for production of productive tillers (Thavaprakaash *et al*., 2017). Comparatively healthy growth of rice plants (more plant height and leaf area) gave rise to more number of tillers in the present study and finally more number of productive tillers hill^{-1}. The number of reproductive tillers was significantly affected by applying conventional fertilizer and in combination with nano-fertilizer. Nanofertilizer may have synergistic effect on the conventional fertilizer for better nutrient absorption by plant cells resulting in optimal growth and tiller production which positively turned into more productive tillers (Benzon *et al*., 2015). Since the application of chemical fertilizers is indispensable for obtaining proper yield in plants, the use of nanofertilizers, especially nano N and Zn treatments, can be a good strategy to optimize the use of fertilizers in rice fields.

C. Effect of foliar application of nano N, Zn and Cu on grain yield of rice

The highest grain yield (Table 2) of 0.511 kg m^{-2} was recorded with the application of 100% NPK + Nano N at active tillering (T_3) which was at par with 75% N + 100% PK + Nano N at active tillering (T_4, 0.506 kgm^{-2}) and 100% NPK + Nano Zn at active tillering and panicle emergence (T_{10}, 0.474 kg m^{-2}), yet 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, thus resulting in increased source and sink capacity (Taiz and Zeiger, 2006). Foliar application of three nano nutrients (N, Zn and Cu) in combination with 100% NPK (T_6) recorded higher grain yield which was at 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 (Chaudhry *et al*., 1973). The lowest grain yield (0.349 kg m^{-2}) was observed in the treatment with no nitrogen and 100% PK (T_2).

Table 2: Efficiency of Foliar Applied Nanonutrients (Nitrogen, Zinc and Copper) on tiller productivity and grain yield of rice at harvest

Treatment	Total no. of tillers hill^{-1}	Productive tillers hill^{-1}	Grain yield (kg m^{-2})
T_1 (100_{NPK})	23.71	19.30	0.440
T_2 (0_N +100_{PK})	15.32	14.69	0.349
T_3 (100_{NPK} + nFN @ AT)	29.15	24.54	0.511
T_4 (75_N + 100_{PK} + nFN @ AT)	27.67	23.81	0.506
T_5 (50_N + 100_{PK} + nFN @ AT)	19.50	14.62	0.433
T_6 (100_{NPK} + nFNZnCu @ AT)	24.83	22.15	0.464
T_7 (75_N + 100_{PK} + nFNZnCu @ AT)	26.76	21.13	0.446
T_8 (50_N + 100_{PK} + nFNZnCu @ AT)	22.33	18.26	0.403
T_9 (100_{NPK} + nFZn @ AT)	25.50	19.41	0.460
T_{10} (100_{NPK} + nFZn @ AT & PE)	28.17	23.42	0.474
T_{11} (100_{NPK} + nFCu @ AT)	21.50	20.68	0.430
T_{12} (100_{NPK} + nFCu @ AT & PE)	20.50	18.16	0.421
SEd	0.89	0.72	0.021
CD (P = 0.05)	2.61	2.11	0.044

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

CONCLUSION

Application of either 100% NPK + Nano N at active tillering or 75% N + 100% PK + Nano N at active tillering had resulted in better growth parameters, higher tiller productivity and grain yield of rice at harvest which was at par with 100% NPK + Nano Zn at active tillering and panicle emergence.

FUTURE SCOPE

Foliar sprays of conventional fertilizers can be compared with their respective nanofertilizers, thus helps in finding out the efficiency of nanofertilizers.

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Conflict of Interest. None.

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