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Standardizing foliar application of Nano nutrients to augment rice (*Oryza sativa* L.) productivity

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Abstract

An investigation was carried out at Annamalai University Experimental Farm, located in the Garden Land Block of the Department of Agronomy, during the 2022–2023 growing season. The aim of the research was to evaluate the effects on the growth and yield characteristics of the Annamalai University 1 Green super Rice (AU 1 GSR) rice cultivar of foliar sprays of nano-N (1500 ml ha^{-1}), nano-Si (175 g ha^{-1}), and nano-Zn (125 g ha^{-1}) and their combinations. The findings demonstrated that using nano fertilizers topically improves rice nutrient uptake efficiency and shields it from environmental stress. A field experiment was conducted as randomized block design with ten treatments and three replications. The treatments consisted of 100% RDN, 75% RDN, Foliar Spray of Nano N @ 1500 ml ha^{-1}, Foliar spray of Nano Zn @ 125 g ha^{-1}, Foliar spray of Nano Si @ 175 g ha^{-1} and control. The study showed that plant height, tiller count, and leaf area index were significantly impacted by combining a 100% recommended dose of nitrogen (RDN) and a foliar fertilizer spray containing nano-zinc and silicon. The results demonstrated that yield and other yield parameters like the number of productive tillers, filled grains in $panicle^{-1}$, test weight, grain yield, straw yield, and harvest index were higher with this treatment. According to the study, applying a foliar spray that contained both nano-silicon (175 g ha^{-1}) and nano-zinc (125 g ha^{-1}) increased the growth, yield, and yield characteristics of rice grains.

Key words : AU1 GSR, Nano-N, Nano-Silicon, Nano-Zinc, Growth and yield.

Rice is the staple food for more than half of the world's population and plays a vital role in many countries' food security. India has the largest rice growing area and ranks second

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in rice production. After China, India is the world's second-largest producer of rice. As a reliable food, rice is essential to India's economy and has a major role in determining agricultural policy. Rice is cultivated worldwide in an area of 160.70 million ha with the production of 497.71 million tonnes, having a productivity of 4.62 t ha^{-1}. India grows rice over an area of 46.78 million hectares, producing 127.93 million tonnes with a yield of 2405 kg ha^{-1} (Anonymous)[3]. Rice is grown over an area of 18.50 lakh hectares in Tamil Nadu, with a production of 72.00 lakh metric tonnes and a productivity of 3.89 t ha^{-1} (Anonymous)[2].

In Tamil Nadu, during samba season, rice is grown prominently for higher productivity compared to other seasons. The adoption of improved practices including nutrient management, weed management and irrigation management is essential to urge higher productivity of crops. Nano-fertilizer is defined as the materials with single unit between 1 and 100 nm in size[5]. The primary target of nano fertilizers in field of agronomy is to increase the plant yield efficiency and diminish losses of nutrients[10]. Nano fertilizers are more effective in improving plant nutrition, increasing the availability of nutrients such as N, P, K, Zn and Si protecting plants from environmental stresses than conventional chemical fertilizers[12].

Nitrogen (N) is a primary nutrient for all the crops. The nitrogen requirement for cereal crops is higher when compared to other crops for its growth, development, and grain production[17]. Most of the rice soils are deficient in N, only a fraction of N requirement can be met with biological nitrogen fixation by cyanobacteria diazotrophic bacteria[9]. Thus, nitrogen fertilizer application is essential to meet the crop requirement. But the efficiency of added fertilizer N in rice depends on the N sources, application method, rate of N as well as management practices[20]. Prilled urea (PU) is applied as N source for rice, but the efficiency of added N from PU is very low, generally it is around 30-45%. This low N use efficiency in rice culture is attributed mainly to denitrification, ammonia volatilization and leaching losses[8]. This necessitates to develop slow-release fertilizers to regulate the nitrification processes thereby N availability be sustained during the crop period.

In rice among the micronutrients zinc (Zn) is an essential micronutrient for humans, animals, and plants. Zinc is directly involved in metabolism of auxins, nitrogen, and it also influences enzymatic activities, stabilization of chromosomal fraction. It also protects the plant cell from oxidative stress[18]. Zinc can be applied in many ways to crop such as soil application, foliar spray, seed treatment, fertigation etc. Foliar or combined soil + foliar application of fertilizers under field conditions has proved to be highly effective and can be a practical way to maximize the zinc accumulation and uptake in grains[4].

Silicon (Si) is the second most abundant element in the soil and its not considered an essential element soil[11]. The Si treatments were considered beneficial to plant growth and plant production. Silicon has a key role in improving growth and increasing rice grain yield and its deficiency can make a serious problem for rice production. Silicon is useful nutrient for healthy growth and sustainable production of rice[19]. The modern nano-Si fertilizers easily penetrate into the leaves and create a thick silicate layer on the leaf surface[14]. Silicon plays an important role in increasing the activity of antioxidant enzymes and enhancing the resistance of abiotic and biotic plant stresses[1.15] reported that, the use of Si increases the rice grain yield by increasing the number of fertile tillers per hill and the number of grains per panicle[7]. Other studies reported that the Si application significantly increased the number of tillers and Si concentration in the plant[21]. Cuong *et al*., reported that increases in Si application, increases the Si absorption and other nutrients such as N, P and K in rice grain and rice straw compared to without Si application.

By use of nano fertilizers, the time and rate for the release of elements coincide and match plant nutritional requirements, thus plants can absorb maximum amount of nutrients and as a consequence, yield surges. Hence these are also refereed to as smart fertilizers.

A field experiment was conducted in in garden land block, Experimental Farm, Department of Agronomy, Annamalai University during crop year of 2022- 2023. The experiment was set up as a randomized block design with ten treatments and three replications with plot area of 4.5 m x 3.5 m. The treatments were as follows: 100% RDN, 100% RDN + Foliar spray of Nano Zn @ 125 g ha^{-1}, 100% RDN + Foliar spray of Nano Si @ 175 g ha^{-1}, 100% RDN + Foliar spray of Nano Zn @ 125 g ha^{-1} + Foliar spray of Nano Si @ 175 g ha^{-1}, 75% RDN, 75% RDN + Foliar Spray of Nano N @ 1500 ml ha^{-1}, 75% RDN + Foliar Spray of Nano N @ 1500 ml ha^{-1} + Foliar spray of Nano Zn @ 125 g ha^{-1}, 75% RDN + Foliar Spray of Nano N @ 1500 ml ha^{-1} + Foliar spray of Nano Si @ 175 g ha^{-1}, 75% RDN + Foliar Spray of Nano N @ 1500 ml ha^{-1} + Foliar spray of Nano Zn @ 125 g ha^{-1} + Foliar spray of Nano Si @175 g ha^{-1}, Control. Half of the recommended dose of nitrogen and potassium was applied basally, and the remaining half was applied in two equal splits, each at active tillering and panicle initiation stage, Full dose of phosphorus was applied as basal. Nano nitrogen were applied at active stages of growth (30 DAT) and during the panicle beginning stage (60 DAT) panicle initiation stage. Both nano zinc and nano silicon were applied at active tillering phase at 30 DAT. While seedling establishment, a thin film of water (2-3 cm) was maintained and then plots were continuously flooded to maintain a ponded layer of 5-6 cm depth during vegetative and after panicle initiation, 2-3 cm depth of water was maintained, and plots were drained 15 days before harvest. Grain yield from net plot area was adjusted to 14% moisture. Biometric observation on Plant height, number tillers m^{-2}, leaf area index, number of productive tillers m^{-2}, filled grains $panicle^{-1}$, test weight, grain yield, straw yield and harvest index. Recommended agronomic practices were followed to raise the experimental crop.

Growth attributes :

Table-1 shows the impact of 100% Recommended Dose of Nitrogen (RDN) coupled with foliar applications of nano-Zn and Si fertilisers on the agro-morphological characteristics of rice. The results indicated that nano-Zn and Si foliar spray, in combination with

100% RDN, had a significant impact on most rice growth indices. The findings showed that plant height (142.98 cm), number of tillers m^{-2} (556), and leaf area index (4.91) were particularly affected by the nano-Zn and Si foliar spray rate. The reason behind the significant improvement in crop development is the balanced intake of nutrients. Zinc increased the auxin level in the plant which led to new shoots thus vigorous growth[18] and the proper use of silicon has been effective in increasing the plant height, number of rice tillers and LAI such that the application of 125 g ha^{-1} of silicon caused a 58% increase in the growth components compared with the control[21].

Yield attributes :

Table-2 shows that the treatments exerted significant influence on the number of productive tillers m^{-2}, number of filled garins panicle^{-1} and test weight. The treatment, T_4 (100% RDN + Foliar spray of Nano Zn @ 125 g ha^{-1} + Foliar spray of Nano Si 175 g ha^{-1}) registered the highest number of productive tillers of 333 and number of filled grains of 168 and thousand grain weight 19.67g. It might be due to the positive effect of Zn and Si on increasing the yield attributes was quite evident over control so that in all treatments where Zn and Si fertilizer was used to forms of NPs foliar application[13].

Table-1. Effect of different nano fertilizers and management practices on growth attributes at harvest of rice (*Oryza sativa* L.)

Treatments	Plant height (cm)	Number of tillers m^{-2}	LAI
T_1 -100% RDN	117.14	447	4.27
T_2 - T_1 + Foliar spray of Nano Zn @ 125 g ha^{-1}	129.31	498	4.57
T_3 - T_1 + Foliar spray of Nano Si @ 175 g ha^{-1}	128.19	494	4.51
T_4 - T_1 + Foliar spray of Nano Zn @ 125 g ha^{-1} + Foliar spray of Nano Si 175 g ha^{-1}	142.98	556	4.91
T_5 - 75% RDN	93.86	389	3.81
T_6 - T_5 + Foliar spray of Nano N @ 1500 ml ha^{-1}	100.77	418	4.04
T_7 - T_5 + Foliar spray of Nano N @ 1500 ml ha^{-1} + Foliar spray of Nano Zn @ 125 g ha^{-1}	121.65	466	4.34
T_8- T_5 + Foliar spray of Nano N @ 1500 ml ha^{-1} + Foliar spray of Nano Si 175 g ha^{-1}	120.78	457	4.30
T_9 - T_5 + Foliar spray of Nano N @ 1500 ml ha^{-1} + Foliar spray of Nano Zn @ 125 g ha^{-1} + Foliar spray of Nano	136.39	527	4.74
Si @175 g ha^{-1}			
T_{10} – Control	73.57	255	3.19
SE d$\pm$	3.11	13.01	0.08
C.D (p=0.05)	6.51	27.45	0.16

RDN- Recommended dose of nitrogen and LAI- Leaf area index

Table-2. No. of productive tillers m^{-2}, no. of filled grains $panicle^{-1}$, test weight (g) as influenced by different nano fertilizers and management practices in rice (*Oryza sativa* L.)

Treatments	Number of productive tillers m^{-2}	Number of filled grains $panicle^{-1}$	Test weight (g)
T_1 -100% RDN	279	145	19.64
T_2 - T_1 + Foliar spray of Nano Zn @ 125 g ha^{-1}	305	157	19.65
T_3 - T_1 + Foliar spray of Nano Si @ 175 g ha^{-1}	299	155	19.65
T_4 - T_1 + Foliar spray of Nano Zn @ 125 g ha^{-1} + Foliar spray of Nano Si 175 g ha^{-1}	333	168	19.67
T_5 - 75% RDN	241	134	19.62
T_6 - T_5 + Foliar spray of Nano N @ 1500 ml ha^{-1}	255	139	19.63
T_7 - T_5 + Foliar spray of Nano N @ 1500 ml ha^{-1} + Foliar spray of Nano Zn @ 125 g ha^{-1}	285	149	19.64
T_8- T_5 + Foliar spray of Nano N @ 1500 ml ha^{-1} + Foliar spray of Nano Si 175 g ha^{-1}	282	147	19.64
T_9 - T_5 + Foliar spray of Nano N @ 1500 ml ha^{-1} + Foliar spray of Nano Zn @ 125 g ha^{-1} + Foliar spray of Nano Si @ 175 g ha^{-1}	319	163	19.66
T_{10} – Control	148	113	19.62
SE d$\pm$	6.91	2.74	0.91
C.D (p=0.05)	12.93	4.86	NS

RDN- Recommended dose of nitrogen

Yield :

Table-3 shows that the treatments exerted significant influence on the grain yield of rice. Among the treatments, T_4, (100% RDN + Foliar spray of Nano Zn @ 125 g ha^{-1} + Foliar spray of Nano Si 175 g ha^{-1}) recorded the highest grain yield of 5793 kg ha^{-1}, straw yield of 8906 kg ha^{-1} and harvest index of 39.81 per cent. This might be due to stimulation effect of zinc and silicon in reducing biotic and abiotic stress. nano zinc resulted in significant increase in the grains per panicle which is directly related to grain yield and straw yield per hill. While, silicon helps in improving the translocation of the metabolites to the grains and straw also decreases the transpiration rate as a result grain yield per plant is increased significantly[16].

The experimental study titled standardizing foliar application of nano nutrients to augment rice (*Oryza sativa* L.) productivity has revealed that the 100% RDN + Foliar spray

Table-3. Grain yield (kg ha^{-1}), straw yield (kg ha^{-1}) and harvest index (%) as influenced by different nano fertilizers and management practices in rice (*Oryza sativa* L.)

Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest index (%)
T_1 -100% RDN	4961	7189	40.83
T_2 - T_1 + Foliar spray of Nano Zn @ 125 g ha^{-1}	5317	7863	40.34
T_3 - T_1 + Foliar spray of Nano Si @ 175 g ha^{-1}	5279	7767	40.46
T_4 - T_1 + Foliar spray of Nano Zn @ 125 g ha^{-1} + Foliar spray of Nano Si 175 g ha^{-1}	5793	8906	39.81
T_5 - 75% RDN	4087	6103	40.11
T_6 - T_5 + Foliar spray of Nano N @ 1500 ml ha^{-1}	4323	6456	40.11
T_7 - T_5 + Foliar spray of Nano N @ 1500 ml ha^{-1} + Foliar spray of Nano Zn @ 125 g ha^{-1}	5042	7342	40.71
T_8- T_5 + Foliar spray of Nano N @ 1500 ml ha^{-1} + Foliar spray of Nano Si 175 g ha^{-1}	5004	7241	40.87
T_9 - T_5 + Foliar spray of Nano N @ 1500 ml ha^{-1} + Foliar spray of Nano Zn @ 125 g ha^{-1} + Foliar spray of Nano @ Si 175 g ha^{-1}	5556	8281	40.15
T_{10} – Control	2097	3813	39.67
SE d$\pm$	113.18	162.9	0.77
C.D (p=0.05)	226.87	325	NS

RDN- Recommended dose of nitrogen

of Nano Zn @ 125 g ha^{-1} + Foliar spray of Nano Si 175 g ha^{-1} has shown significant growth, yield attributes and yield as compared to other treatments. Treatment may increase production, growth, and yield due to favourable physiological conditions and nutrition management.

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