

Effect of nano nitrogen and nano zinc on growth and yield of paddy in paddy-paddy cropping system

ABSTRACT

An investigation on nano nitrogen and nano zinc with different levels of nitrogen approaches on growth and yield of paddy was conducted during *rabi* and *kharif* seasons of 2020-21 and 2021-22 at Krishi Vigyana Kendra, Gangavathi, Koppal, Karnataka, India. The experiment was laid out in split-split plot design with three replications, which consisted of four levels of nitrogen in main plots, three levels of nano nitrogen in sub plots and two levels of nano zinc in sub-sub plots. The treatment with application of 125 per cent **Recommended Dose of Nitrogen** (RDN) has recorded significantly taller plants (97.11 and 96.54 cm), higher number of tillers hill⁻¹ (19.65 and 18.14) and total dry matter (70.06 and 64.54 g hill⁻¹) at harvest stage of crop and the **Soil Plant Analysis Development** (SPAD) values (46.69 and 42.60) and **Normalized Difference Vegetation Index** (NDVI) values (0.85 and 0.82) at flowering stage of crop. Similarly, foliar spray of nitrogen @ 4000 ppm has recorded significantly higher plant height (95.44 and 91.33 cm), higher number of tillers hill⁻¹ (17.75 and 16.01), total dry matter (66.84 and 62.31 g hill⁻¹) SPAD values at flowering stage (44.89 and 41.29), NDVI values at flowering stage (0.81 and 0.74), grain yield (5623 & 6840 kg ha⁻¹) and straw yield (5352 and 6581 kg ha⁻¹). Interaction effect showed non-significant effect with different combination treatments.

KEYWORDS: Nano nitrogen; nano zinc; foliar spray; growth;

INTRODUCTION

Sustainability of natural resources such as soil and water for crops production is a major challenge with burgeoning population pressure. There is a need to balance between increasing crop production without compromising soil health and environmental sustainability. In Asia, rice is the principal staple crop where ~90 percent of the global rice being grown and consumed. In India, it occupies ~43.8 m ha of cultivable area with production of ~118.87 mt (Directorate of Economics and Statistics, 2021). Intensive mono-cropped system of rice cultivation has commenced to show declining trend in rice yield, where imbalance nutrient management and decreasing soil organic matter are the major accountable factors for the declining the rice yield (Sureka *et al.*, 2003).

Fertilizers are indispensable in agricultural production system. Application of fertilizers started in 1960's which closely coincided with the introduction of fertilizer responsive varieties in Indian agriculture. Although fertilizer application remarkably improved the crop growth and enhanced the yields of several crops but the yields got plateaued due to the low fertilizer response ratio, imbalanced fertilization and increased

intensities of micronutrient deficiencies across the country. Within the set of challenges faced by the present agriculture system, imbalanced fertilization is one of the most critical factor to be considered for nitrogen (N) management. Since N fertilization reveals universal response in crops besides low price of urea due to decontrol (subsidized rate), farmers started the use of nitrogenous fertilizers particularly urea irrationally, which has led to the **current nitrogen: phosphorus: potassium** (NPK) ratio of 8.2: 3.2: 1 while optimal ratio is stipulated as 4: 2: 1 in cereals. This is very serious issue causing nitrate pollution in ground water and eutrophication in aquatic system. This necessitates to develop slow release fertilizers to regulate the nitrification processes thereby N availability be sustained during the crop period.

Nowadays, application of nano particles (NPs) is gaining importance in agriculture. Nanotechnology deals with small particles with the dimension of 1-100 nm (one billionth of a meter). These particles have high surface mass ratio and are capable of improving the efficiency of agricultural inputs including fertilizers. Nano fertilizers have unique physico-chemical properties and the potential to enhance the plant metabolism (Giraldo *et al.*, 2014). 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 boost the target activity (DeRosa *et al.*, 2010). Nanotechnology has potential to develop slow release efficient fertilizers (Sharma, 2008) which eventually reduce the nutrient losses and augment the existing fertilizer use efficiency.

Therefore, achieving sustainable agriculture with more yields besides maintaining the environmental and soil health is the goal of researchers in agriculture. In such manner, utilization of chemical fertilizers has long been condemned because of their harmful impacts on the environment and quality of agricultural products and there is a need to explore better alternatives such as nano particles with small size and large surface area are expected to be the ideal candidates for use as fertilizers in crops to improve fertilizer use efficiency and to minimize the detrimental effects of fertilizers on the environment. Use of nano N and nano **nano zinc** (Zn) fertilizers are the better alternatives to increase nutrient use efficiency. In the view of above, the newly introduced nano N and nano Zn fertilizers by **Indian Farmers Fertiliser Cooperative Limited** (IFFCO Ltd). These products have been researched and developed indigenously at the IFFCO Nano Biotechnology Research Centre (NBRC) at Kalol Unit, Gujarat. Nano nitrogen contains 4% of N and nano zinc contains 1% of Zn.

Objective of the experiment

To evaluate the effect of nano nitrogen and nano zinc on growth and yield of transplanted paddy - paddy cropping system

MATERIALS AND METHODS

Experimental site and soil

The field experiments were conducted in Krishi Vigyana Kendra, Gangavathi (Dist: Koppal), India during *rabi* season of 2020-2021 and *kharif and rabi* season of 2021-2022. The experiment site situated in the Northern Dry Zone (Zone 3) of Karnataka state lying between 15° 15' 40" North (latitude) and 76° 31' 40" East (longitude) with an altitude of 419 m above mean sea level.

The soil of the experimental site was clay in texture with saline pH (8.03), medium electrical conductivity (EC) (1.26dS m⁻¹) and high in organic carbon (OC) (7.01 g kg⁻¹). The soil was low in available nitrogen (191.25kg ha⁻¹), high in available phosphorus (51.67 kg ha⁻¹) & medium in available potassium (302.77 kg ha⁻¹) and available sulphur (18.31 mg kg⁻¹). The diethylene triamine penta acetic acid (DTPA) extractable Zn, Fe, Mn and Cu were in sufficient range with values 1.05, 5.51, 5.34 and 3.73 mg kg⁻¹, respectively.

Salient features of the cultivar RNR- 15048

The variety used was RNR 15048 (Telengana Sona). This paddy variety has low glycemic index of 51 and 5 per cent more protein compared to BPT-5204. It has unique grain size, short slender, high grain yield potential, good cooking quality and above all robust blast resistance characteristics. One of the striking qualities of this paddy variety is that it can be cultivated during both *kharif* and *rabi* seasons in a short duration of about 125 days.

Experimental details

The experiment was laid out in a split-split plot design with twenty four treatments and three replications. The details of treatment are shown in Table 1.

Table 1: Treatment details

| Main plot: Soil nitrogen management (M) | Subplot: Foliar spray (FS) of nano nitrogen (N) | Subplot: Foliar spray (FS) of nano zinc (Z) |
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| M₁ : 100 % RDF (ZnSO ₄ .7H ₂ O @ 25 kg ha ⁻¹) M₂ : 75 % RDN M₃ : 100 % RDN M₄ : 125 % RDN | N₁ : FS of nano N @ 2000 ppm (2 ml L ⁻¹) N₂ : FS of nano N @ 4000 ppm (4 ml L ⁻¹) N₃ : FS of nano N @ 6000 ppm (6 ml L ⁻¹) | Z₁ : FS of nano Zn @ 2000 ppm (2 ml L ⁻¹) Z₂ : FS of nano Zn @ 3000 ppm (3 ml L ⁻¹) |
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RDF: Recommended Dose Fertilizer

RDN: Recommended Dose Nitrogen

Recommended dose of P and K was applied through conventional fertilizer and farmyard manure (FYM) was common for all the treatments except absolute control. Absolute control (water spray) was maintained separately outside the layout of the experiment for comparison. Nano nitrogen and nano zinc contains 4 % N and 1 % Zn, respectively.

Growth and yield measurements

The plant height and number of tillers hill⁻¹ of paddy in each season was recorded at panicle initiation and crop harvest stage. Chlorophyll meter readings were recorded at active tillering, panicle initiation and flowering stages. The top most fully expanded leaf was chosen for SPAD measurement, as described by Babu *et al.* (2000). The SPAD readings were taken at random for each plot and the average was noted. The Green Seeker hand held optical sensor unit (Trimble Navigation Limited, Sunnyvale, CA, USA) was used for NDVI measurement in the study. The sensor emits brief bursts of red and infrared light and then measures the amount of each that is reflected back. The instrument was held 2-3 feet above the plant canopy and moved around the plot randomly along the crop canopy to measure the average NDVI value for each plot. The observations were recorded at active tillering, panicle initiation and flowering stages of crop. In each season, the above ground biomass of all plants was manually harvested separately from the net plot, threshed and dried in sun. The grains were cleaned and weight was recorded in kg hectare (kg ha⁻¹).

Statistical analysis

The experimental data were subjected to statistical scrutiny to find out the influence of treatments on growth, yield and nutrient uptake by paddy. Further the effects were tested at 5% level of significance (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

The data on growth, yield and nutrient uptake paddy are shown in Table 2 to 5. There was a slight difference in these parameters during both *kharif* and *rabi* season experiments, but the pattern of response was similar. Hence, only pooled data of the *rabi* season and one year data of *kharif* season have been used to emphasize the results.

Plant height (cm) of paddy

Among different nitrogen levels, 125 per cent RDN (M₄) recorded higher plant height at panicle initiation (PI) and harvest stage (HS) of paddy crop (82.09 & 97.11 and 78.51 & 96.54 cm during *rabi* and *kharif* season, respectively) as compared to other treatments of different nitrogen levels (Table 2). Similarly, significant higher plant height was recorded by foliar spray of nano N @ 4000 ppm (N₂: 79.36 & 95.44 and 73.75 & 91.33 cm at PI & HS during *rabi* and *kharif* season, respectively) followed by FS of nano N @ 2000 ppm (N₁) and 6000 ppm (N₃).

There was no significance difference among the foliar spray of nano Zn but higher plant height was recorded by the FS of nano Zn @ 2000 ppm at PI and HS of paddy crop (77.89 & 93.97 and 72.35 & 89.59 cm during *rabi* and *kharif* season, respectively) followed by foliar spray of nano Zn @ 3000 ppm (Table 2). While, absolute control registered a lower plant height at PI and HS of paddy crop (65.19 & 80.40 and 63.99 & 79.34 cm during *rabi* and *kharif* season, respectively).

Interaction effect among different levels of nitrogen, foliar spray of nano N and nano Zn showed non-significant difference but the higher plant height (Table 2) was recorded with the combination of 125 % RDN along with foliar spray of nano N @ 4000 ppm and nano Zn @ 2000 ppm at PI and HS of paddy crop (86.11 & 101.13 and 81.80 & 100.58 during *rabi* and *kharif* season, respectively) while, lower plant height was recorded with the combination of 75 % RDN along with foliar spray of nano N @ 6000 ppm and nano Zn @ 3000 ppm (70.83 & 87.81 and 65.15 & 80.78 during *rabi* and *kharif* season, respectively).

During *rabi* and *kharif* season of the study, an increasing trend in plant height was observed across the growth stages of paddy in all the treatments. Different levels of nitrogen affected the plant height significantly with the age of paddy crop and recorded higher in 125 per cent RDN (M₄) followed by 100 per cent RDF with ZnSO₄.7H₂O at 25 kg ha⁻¹ (M₁), 100 per cent RDN (M₃) and 75 per cent RDN (M₁). This could be due to increased vegetative growth of plant with higher levels of N supplied to plant. In parallel, Reddy *et al.* (2007)

reported that increased rates of N application significantly improved the plant height as compared to control.

Improved plant height under foliar spray of nano N @ 4000 ppm and foliar spray of nano Zn @ 2000 ppm was accrued due to sufficient nutrients supply as per crop demand as compared to FS of nano N @ 2000 ppm, 6000 ppm and foliar spray of nano Zn @ 3000 ppm. Increase in the plant height could be ascribed to adequate supply of nitrogen and zinc which accelerate the activity of enzyme and auxin metabolism in the plant, which in turn enlarge the cell and cell elongation might resulted in taller plants. This is in conformity with the works of Torres-Olivar *et al.* (2014) and Nithya *et al.* (2018). Benzon *et al.* (2015) revealed that plant height was more enhanced when nano-fertilizer was combined with conventional ones due to the reason that nano fertilizer can either provide nutrients for the plant or aid in the transport or absorption of available nutrients resulting in better crop growth.

The enhancement in plant height by application of 125 per cent RDN along with foliar spray of nano N @ 4000 ppm with foliar spray of nano Zn @ 2000 ppm ($M_4N_2Z_1$) over other treatments might be due to enhanced availability of both macro and micro nutrients besides improvement in soil microbial activity. The enhanced uptake of these nutrients might have resulted in increased vegetative growth of plant.

Number of tillers hill⁻¹

Significant difference with respect to number of tillers hill⁻¹ was observed with different levels of nitrogen and foliar spray of nano N across the growth stages of paddy.

Similar to plant height, number of tillers hill⁻¹ increased significantly by 125 per cent RDN at PI and FS of paddy crop (M_4 : 17.03 & 19.65 and 15.49 & 18.14 during *rabi* and *kharif* season, respectively) followed by M_1 , M_3 and M_2 . Similarly significant higher number of tillers hill⁻¹ was recorded in different stages of paddy crop by foliar spray of nano N @ 4000 ppm (N_2 : 15.32 & 17.75 and 13.67 & 16.01 during *rabi* and *kharif* season, respectively) followed by foliar spray of nano N @ 2000 ppm and 6000 ppm (Table 3).

Foliar spray of nano Zn @ 2000 ppm recorded higher number of tillers hill⁻¹ (14.49 & 16.83 and 12.79 & 14.95 at PI and FS of paddy crop during *rabi* and *kharif* season, respectively), which was on par with the foliar spray of nano Zn @ 3000 ppm (Table 3). While, absolute control registered lower number of tillers hill⁻¹ at PI and FS of paddy crop (9.42 & 11.24 and 9.80 & 11.37 during *rabi* and *kharif* season, respectively).

Combined application of different levels of nitrogen, foliar spray of nano N and nano Zn showed non-significant difference but higher number of tillers hill⁻¹ (Table 3) was recorded with the combination of 125 % RDN along with foliar spray of nano N @ 4000 ppm and nano Zn @ 2000 ppm (18.43 & 21.20 and 16.98 & 20.00 during *rabi* and *kharif* season, respectively), while lower number of tillers hill⁻¹ was recorded with the combination of 75 % RDN along with foliar spray of nano N @ 6000 ppm and nano Zn @ 3000 ppm (11.46 & 13.47 and 9.57 & 11.18 during *rabi* and *kharif* season, respectively). It was probably due to increased supply of nitrogen and zinc to plants, which have accelerated the activity of enzymes involved in photosynthesis, carbohydrates metabolism, protein synthesis, cell division and cell elongation. This is in conformity with the work of Beerasha (2018) and Uma (2019). Wijebandara (2007) reported that the availability of required quantity of N for long time was probably responsible for producing a greater number of effective tillers as is the case with higher levels of N applied in the present study. The findings are in line with the observations of Sankalpa (2013) who reported that increased number of tillers per hill could be expected up to 40 % N in excess of RDF N. Manzoor *et al.* (2006), Wijebandara (2007) and Choudhary and Pandey (2009) also reported similar observations.

The significant increase in number of tillers per hill⁻¹ by nano N could be expected up to foliar spray of 4000 ppm N. Kumari *et al.* (2000) also reported increase in number of productive tillers up to a certain level of N (120 kg ha⁻¹) and not beyond that. The results are in agreement with the findings of Manzoor *et al.* (2006) and Wijebandara (2007). Nano-fertilizers induced nitrate reductase and increased activity of chloroplast (Hong *et al.*, 2005), rubisco (Gao *et al.*, 2006) and antioxidant enzyme system (Nekrasova *et al.*, 2011) that might be the possible underlying mechanism for enhanced growth and increase in number of tillers.

Total dry matter production (g hill⁻¹)

Application of 125 per cent RDN recorded higher total dry matter production at PI and HS of paddy crop (27.55 & 70.06 and 24.01 & 64.54 g hill⁻¹ during *rabi* and *kharif* season, respectively) followed by 100 per cent RDF + ZnSO₄.7H₂O @ 25 kg ha⁻¹, 100 per cent RDN and 75 per cent RDN (Table 4). On the other hand, significantly higher total dry matter production was recorded in all the stages of paddy crop by FS of nano N @ 4000 ppm (26.26, & 66.84 and 23.53 & 62.31 g hill⁻¹ during *rabi* and *kharif* season, respectively) as compared to FS of nano N @ 2000 ppm and 6000 ppm.

No significance difference was recorded among the FS of nano Zn but higher total dry matter production was recorded by the FS of nano Zn @ 2000 ppm at PI and HS of paddy crop (25.41 & 64.67 and 22.76 & 60.29 g hill⁻¹ during *rabi* and *kharif* season, respectively) followed by FS of nano Zn @ 3000 ppm.

Combined application of 125 per cent RDN along with FS of nano N @ 4000 ppm and nano Zn @ 2000 ppm recorded higher total dry matter production at PI and HS of paddy crop (28.78 & 73.18 and 25.08 & 67.41g hill⁻¹ during *rabi* and *kharif* season, respectively) while, lower total dry matter production was recorded with the combination of 75 per cent RDN along with FS of nano N @ 2000 ppm and nano Zn @ 3000 ppm at PI and HS of paddy crop (22.24 & 58.04 and 19.89 & 54.51 g hill⁻¹ during *rabi* and *kharif* season, respectively). Control treatment recorded significantly lower total dry matter production values at PI and HS of paddy crop (17.94 & 47.33 and 18.46 & 47.25 g hill⁻¹ during *rabi* and *kharif* season, respectively).

One of the most important growth parameters which is a measure of total photosynthesis and respiratory tissues is total dry matter production. Total dry weight of plant was increased over time with the advancement of crop age. There exists a direct relation between plant height and number of tillers with dry matter production. The treatment with 125 per cent RDN (M₄) was associated with increased **plant height and number of tillers**.

On the other hand, FS of nano N also significantly increased the total dry matter production at all stages of crop growth due to cumulative vigorous growth which in turn put forth more photosynthetic surface, chlorophyll formation, biomass and more nutrient uptake. Increased crop growth rate is attributed to higher dry matter accumulation at periodic intervals. These results are in corroboration with the findings of Jafarzadeh *et al.* (2013), Mahmoodzadeh *et al.* (2013), Kumar *et al.* (2014), Benzon *et al.* (2015), Hafeez *et al.* (2015) and Aziz *et al.* (2016).

Chlorophyll content

Higher SPAD values were recorded at different growth stages with application of 125 per cent RDN at AT, PI and FS of paddy crop (31.57, 43.59 & 46.69 and 29.18, 40.19 & 42.60 during *rabi* and *kharif* season, respectively) as compared to other treatment (**Table 5**). Similarly significant higher SPAD values were recorded at AT, PI and FS of paddy crop by FS of nano N @ 4000 ppm (30.42, 41.86 & 44.89 and 27.96, 38.73 & 41.29 during *rabi* and

kharif season, respectively) followed by to FS of nano N @ 2000 ppm and FS of nano N @ 6000 ppm.

Among FS of nano Zn, higher SPAD values were recorded by the FS of nano Zn @ 2000 ppm (29.94, 41.16 & 44.14 and 27.49, 38.11 & 40.59 during *rabi* and *kharif* season, respectively) which was on par with FS of nano Zn @ 3000 ppm. Control treatment recorded significantly lower SPAD values at AT, PI and FS of paddy crop (24.83, 31.06 & 35.14 and 24.86, 29.38 & 33.44 during *rabi* and *kharif* season, respectively).

Interaction effect among different nitrogen levels, FS of nano N and FS of nano Zn showed non-significant difference but the higher SPAD values was recorded with the combination of 125 per cent RDN along with FS of nano N @ 4000 ppm and nano Zn @ 2000 ppm (32.04, 44.24 & 47.40 and 29.64, 40.79 & 43.27 during *rabi* and *kharif* season, respectively) while, lower SPAD values was recorded with the combination of 75 per cent RDN along with FS of nano N @ 6000 ppm and nano Zn @ 3000 ppm (27.54, 37.40 & 40.25 and 24.86, 35.06 & 37.54 during *rabi* and *kharif* season, respectively) at AT, PI and FS of paddy crop.

SPAD values indicates the greenness *i.e.*, chlorophyll content of leaves. Higher SPAD value obtained due to the absorption and assurance of sufficient supply of nutrients mainly the nitrogen to the leaves (Farnia and Omidi, 2015). Nano fertilizers improved the N, P and K uptake in the crop as indicated in Table 5 and 7. As nitrogen is the major component in the chlorophyll synthesis, this might have contributed to higher chlorophyll content in nano fertilizer applied treatments. These results are in accordance with Rose *et al.* (2015). In addition, application of nano Zn also promotes the synthesis of chlorophyll, which acts as a structural and catalytic component of proteins, enzymes and as co-factor for normal development of pigment biosynthesis (Balashouri and Prameeladevi, 1995).

Normalized Difference Vegetation Index (NDVI)

The data pertaining to NDVI differed significantly among different nitrogen levels and FS of nano N (Table 6). Among different nitrogen levels 125 per cent RDN recorded higher NDVI values at AT, PI and FS of paddy crop (0.53, 0.72 & 0.85 and 0.49, 0.68 & 0.82 during *rabi* and *kharif* season, respectively) followed by M₁, M₃ and M₂. Similarly significant higher NDVI values were recorded in different stages of paddy crop by FS of nano N @ 4000

ppm (0.50, 0.68 & 0.81 and 0.46, 0.62 & 0.74 during *rabi* and *kharif* season, respectively) as compared to FS of nano N @ 2000 ppm and 6000 ppm.

No significance difference was recorded among the FS of nano Zn but higher NDVI values were recorded by the FS of nano Zn @ 2000 ppm at AT, PI and FS of paddy crop (0.48, 0.67 & 0.80 and 0.44, 0.60 & 0.72 during *rabi* and *kharif* season, respectively) as compared to FS of nano Zn @ 3000 ppm. Control treatment recorded significantly lower NDVI values at AT, PI and FS of paddy crop (0.28, 0.43 & 0.57, and 0.26, 0.36 & 0.51 during *rabi* and *kharif* season, respectively).

Interaction effect among different levels of nitrogen, FS of nano N and FS of nano Zn showed non-significant difference but the higher NDVI values were recorded with the combination of 125 per cent RDN along with FS of nano N @ 4000 ppm and nano Zn @ 2000 ppm (0.56, 0.76 & 0.88 and 0.52, 0.71 & 0.86 during *rabi* and *kharif* season, respectively) while, lower NDVI values was recorded with the combination of 75 per cent RDN along with FS of nano N @ 6000 ppm and nano Zn @ 3000 ppm (0.40, 0.56 & 0.71 and 0.36, 0.49 & 0.59 during *rabi* and *kharif* season, respectively) at AT, PI and FS of paddy crop.

NDVI values indicate the extent of canopy coverage and healthy status of plants indirectly suggesting good photosynthetic area. Application of nitrogen fertilizer may enhance the photosynthetic light capture in leaf blades, possibly increasing turf growth and quality under reduced light conditions (Trenholm *et al.*, 2004). Canopy/vegetation coverage and healthy status of plants are determined by the extent of green leaf area covering the ground. In the present study the higher NDVI associated with $M_4N_2Z_1$, was due to higher leaf area and LAI of that treatment.

Yield of paddy (kg ha^{-1})

Grain and straw yield differed significantly between different levels of nitrogen and foliar spray of nano N (Table 7). Among the different levels of nitrogen, addition of 125 per cent RDN (M_4) registered higher grain and straw yield of 5659 & 5405 kg ha^{-1} and 6836 and 6595 kg ha^{-1} which was on par with 100 per cent RDN with $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ @ 25 kg ha^{-1} (M_1 : 5485 & 5217 kg ha^{-1} and 6690 & 6417 kg ha^{-1}) and 100 per cent RDN (M_3 : 5375 & 5113 kg ha^{-1} and 6557 and 6290 kg ha^{-1}). While, lower grain and straw yield was noticed with 75 per

cent RDN (M_2 : 5206 & 4942 kg ha⁻¹ and 6353 and 6129 kg ha⁻¹) during *rabi* and *kharif* season, respectively.

Irrespective of foliar spray of nano N, significantly higher grain and straw yield was observed in treatment with foliar spray of nano N @ 4000 ppm (N_2 : 5623 & 5352 kg ha⁻¹ and 6840 and 6581 kg ha⁻¹) followed by foliar spray of nano N @ 2000 ppm (N_1 : 5359 & 5101 kg ha⁻¹ and 6522 and 6273 kg ha⁻¹) and foliar spray of nano N @ 6000 ppm (N_3 : 5312 & 5056 kg ha⁻¹ and 6465 and 6218 kg ha⁻¹) during *rabi* and *kharif* season, respectively.

While, no significant difference was observed in foliar spray of nano Zn, however, higher grain and straw yield (5479 & 5215 kg ha⁻¹ and 6667 and 6413 kg ha⁻¹) was noticed in nano Zn @ 2000 ppm (Z_1) and was on par with the Z_2 (foliar spray of nano N @ 3000 ppm: 5384 & 5124 kg ha⁻¹ and 6551 & 6302 kg ha⁻¹ during *rabi* and *kharif* season, respectively). While, lower grain and straw yield of 3688 & 3668 kg ha⁻¹ and 4588 and 4569 kg ha⁻¹ was registered in absolute control, during *rabi* and *kharif* season, respectively.

Grain and straw yield increases with the increasing level of N from 100 to 150 per cent RDN was reported by Bhowmick and Nayak (2000). Higher grain and straw yield at M_4 may be ascribed to the overall improvement in plant vigour and production of sufficient photosynthates owing to greater availability of nutrients subsequently resulting in better manifestation of yield attributes (Choudhary and Pandey, 2009). The increase in grain and straw yield due to combined application of nano particles of nano N as foliar at 4000 ppm at tillering and panicle initiation and foliar spray of nano Zn at 2000 ppm at tillering stage is mainly attributed to higher grain and straw yield components and also stimulation effect of zinc which helps in increasing enzymatic activity. Muthukumararaja & Sriramachandrasekharan (2012) reported that grain and straw yield of rice increase is due to enhanced synthesis of carbohydrate and their transport to the site of grain production.

Conclusions

Spraying of liquid nano nitrogen and nano zinc has increased **paddy** crop yield by increasing plant growth parameters. Spraying of nano nitrogen and nano zinc proved to be beneficial particularly under transplanted conditions. This also led to saving of mineral N in the form of nitrogen fertilizer thereby decreased the accumulation of N in the soil. Application of 125 per cent RDN along with foliar spray of nano N @ 4000 ppm at active tillering & panicle initial stages and foliar spray of nano Zn @ 2000 ppm at active tillering

stage of paddy was found to be on par with 100 per cent RDN along with foliar spray of nano N @ 4000 ppm at active tillering & panicle initial stages and foliar spray of nano Zn @ 2000 ppm at active tillering stage in terms of crop yield. Hence for effective management of nano fertilizers in paddy, the application of 100 per cent RDN along with foliar spray of nano N @ 4000 ppm and foliar spray of nano Zn @ 2000 ppm was recommended.

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Conflict of interest

No potential conflict of interest was reported by the authors.

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Table 2: Plant height (cm) at panicle initiation and harvest stages of paddy as influenced by different levels of nitrogen along with foliar spray of nano nitrogen and nano zinc during *rabi* (pooled 2021 and 2022) and *kharif* (2021)

| MxNxZ | | Panicle initiation | | | | | | | | At harvest | | | | | | | |
|-----------------|----------------|------------------------------------|----------------|----------------|--------------|---------------------|----------------|----------------|--------------|------------------------------------|----------------|----------------|--------------|---------------------|----------------|----------------|--------------|
| | | <i>Rabi</i> (Pooled 2021 and 2022) | | | | <i>Kharif</i> -2021 | | | | <i>Rabi</i> (Pooled 2021 and 2022) | | | | <i>Kharif</i> -2021 | | | |
| | | N ₁ | N ₂ | N ₃ | MxZ | N ₁ | N ₂ | N ₃ | MxZ | N ₁ | N ₂ | N ₃ | MxZ | N ₁ | N ₂ | N ₃ | MxZ |
| M ₁ | Z ₁ | 78.47 | 79.86 | 76.38 | 78.24 | 73.67 | 75.35 | 71.60 | 73.54 | 94.77 | 96.16 | 92.68 | 94.54 | 91.72 | 93.81 | 89.15 | 91.56 |
| | Z ₂ | 76.88 | 78.76 | 74.70 | 76.78 | 72.12 | 74.18 | 71.35 | 72.55 | 93.18 | 95.07 | 90.99 | 93.08 | 89.79 | 92.36 | 88.83 | 90.32 |
| M ₂ | Z ₁ | 73.61 | 76.07 | 71.62 | 73.77 | 66.83 | 69.02 | 65.54 | 67.13 | 90.60 | 93.06 | 88.61 | 90.76 | 82.86 | 85.58 | 81.26 | 83.24 |
| | Z ₂ | 72.81 | 73.78 | 70.83 | 72.48 | 66.44 | 68.12 | 65.15 | 66.57 | 89.80 | 90.78 | 87.81 | 89.46 | 82.38 | 84.46 | 80.78 | 82.54 |
| M ₃ | Z ₁ | 76.68 | 78.76 | 74.60 | 76.68 | 70.19 | 70.70 | 68.51 | 69.80 | 92.68 | 94.77 | 90.60 | 92.68 | 87.02 | 87.66 | 84.94 | 86.54 |
| | Z ₂ | 75.37 | 77.48 | 73.11 | 75.32 | 69.02 | 70.31 | 67.73 | 69.02 | 91.37 | 93.48 | 89.11 | 91.32 | 85.58 | 87.18 | 83.98 | 85.58 |
| M ₄ | Z ₁ | 82.24 | 86.11 | 80.25 | 82.87 | 78.06 | 81.80 | 76.89 | 78.92 | 97.26 | 101.13 | 95.27 | 97.89 | 95.98 | 100.58 | 94.55 | 97.04 |
| | Z ₂ | 81.15 | 84.02 | 78.76 | 81.31 | 77.28 | 80.51 | 76.51 | 78.10 | 96.16 | 99.04 | 93.78 | 96.33 | 95.03 | 98.99 | 94.08 | 96.03 |
| N | | 77.15 | 79.36 | 75.03 | | 71.70 | 73.75 | 70.41 | | 93.23 | 95.44 | 91.11 | | 88.80 | 91.33 | 87.20 | |
| | | MxN | | | M | MxN | | | M | MxN | | | M | MxN | | | M |
| M | M ₁ | 77.67 | 79.31 | 75.54 | 77.51 | 72.89 | 74.77 | 71.48 | 73.05 | 93.98 | 95.62 | 91.84 | 93.81 | 90.75 | 93.08 | 88.99 | 90.94 |
| | M ₂ | 73.21 | 74.93 | 71.23 | 73.12 | 66.64 | 68.57 | 65.35 | 66.85 | 90.20 | 91.92 | 88.21 | 90.11 | 82.62 | 85.02 | 81.02 | 82.89 |
| | M ₃ | 76.03 | 78.12 | 73.85 | 76.00 | 69.60 | 70.51 | 68.12 | 69.41 | 92.03 | 94.13 | 89.85 | 92.00 | 86.30 | 87.42 | 84.46 | 86.06 |
| | M ₄ | 81.69 | 85.06 | 79.51 | 82.09 | 77.67 | 81.15 | 76.70 | 78.51 | 96.71 | 100.09 | 94.52 | 97.11 | 95.50 | 99.79 | 94.31 | 96.54 |
| | | NxZ | | | Z | NxZ | | | Z | NxZ | | | Z | NxZ | | | Z |
| Z | Z ₁ | 77.75 | 80.20 | 75.71 | 77.89 | 72.19 | 74.22 | 70.64 | 72.35 | 93.83 | 96.28 | 91.79 | 93.97 | 89.40 | 91.91 | 87.48 | 89.59 |
| | Z ₂ | 76.55 | 78.51 | 74.35 | 76.47 | 71.22 | 73.28 | 70.19 | 71.56 | 92.63 | 94.59 | 90.42 | 92.55 | 88.20 | 90.75 | 86.92 | 88.62 |
| Control | | 65.19 | | | | 63.99 | | | | 80.40 | | | | 75.34 | | | |
| | | S.Em ± | | CD at 5 % | | S.Em ± | | CD at 5 % | | S.Em ± | | CD at 5 % | | S.Em ± | | CD at 5 % | |
| M | | 0.99 | | 3.31 | | 0.58 | | 2.01 | | 0.64 | | 2.21 | | 0.57 | | 1.96 | |
| N | | 0.96 | | 2.19 | | 0.64 | | 1.91 | | 0.95 | | 2.13 | | 0.98 | | 2.34 | |
| Z | | 0.66 | | NS | | 0.64 | | NS | | 0.92 | | NS | | 0.77 | | NS | |
| M x N | | 1.93 | | NS | | 1.27 | | NS | | 1.89 | | NS | | 1.96 | | NS | |
| M x Z | | 1.33 | | NS | | 1.29 | | NS | | 1.85 | | NS | | 1.54 | | NS | |
| N x Z | | 1.15 | | NS | | 1.12 | | NS | | 1.60 | | NS | | 1.33 | | NS | |
| M x N x Z | | 2.30 | | NS | | 2.23 | | NS | | 3.20 | | NS | | 2.66 | | NS | |
| Control vs Rest | | 3.52 | | 6.08 | | 2.13 | | 3.68 | | 2.34 | | 4.05 | | 2.08 | | 3.60 | |

NOTE:

NS : Non significant

Main plot : Soil nitrogen management (M)

Sub plot : Foliar spray of nano nitrogen (N)

Sub-sub plot : Foliar spray of nano zinc (Z)

M₁ : 100 % RDF (ZnSO₄.7H₂O @ 25 kg ha⁻¹)

N₁ : FS of nano N @ 2000 ppm

Z₁ : FS of nano Zn @ 2000 ppm

M₂ : 75 % RDN

N₂ : FS of nano N @ 4000 ppm

Z₂ : FS of nano Zn @ 3000 ppm

M₃ : 100 % RDN M₄ : 125 % RDN

N₃ : FS of nano N @ 6000 ppm

Table 3: Number of tillers per hill at panicle initiation and harvest of paddy stages as influenced by different levels of nitrogen along with foliar spray of nano nitrogen and nano zinc during *rabi* (pooled 2021 and 2022) and *kharif* (2021)

| MxNxZ | | Panicle initiation | | | | | | | | At harvest | | | | | | | |
|-----------------|----------------|------------------------------------|----------------|----------------|--------------|---------------------|----------------|----------------|--------------|------------------------------------|----------------|----------------|--------------|---------------------|----------------|----------------|--------------|
| | | <i>Rabi</i> (Pooled 2021 and 2022) | | | | <i>Kharif</i> -2021 | | | | <i>Rabi</i> (Pooled 2021 and 2022) | | | | <i>Kharif</i> -2021 | | | |
| | | N ₁ | N ₂ | N ₃ | MxZ | N ₁ | N ₂ | N ₃ | MxZ | N ₁ | N ₂ | N ₃ | MxZ | N ₁ | N ₂ | N ₃ | MxZ |
| M ₁ | Z ₁ | 14.71 | 15.55 | 13.87 | 14.71 | 13.02 | 13.91 | 12.13 | 13.02 | 17.07 | 18.01 | 16.13 | 17.07 | 15.21 | 16.25 | 14.16 | 15.21 |
| | Z ₂ | 14.47 | 15.31 | 13.75 | 14.51 | 12.76 | 13.66 | 12.00 | 12.81 | 16.81 | 17.72 | 15.98 | 16.84 | 14.91 | 15.95 | 14.01 | 14.96 |
| M ₂ | Z ₁ | 12.42 | 13.38 | 11.58 | 12.46 | 10.59 | 11.62 | 9.70 | 10.64 | 14.53 | 15.60 | 13.57 | 14.57 | 12.37 | 13.57 | 11.33 | 12.42 |
| | Z ₂ | 11.94 | 13.02 | 11.46 | 12.14 | 10.08 | 11.23 | 9.57 | 10.30 | 14.00 | 15.19 | 13.47 | 14.22 | 11.78 | 13.12 | 11.18 | 12.03 |
| M ₃ | Z ₁ | 13.50 | 14.47 | 12.66 | 13.54 | 11.74 | 12.76 | 10.85 | 11.79 | 15.80 | 16.80 | 14.78 | 15.79 | 13.72 | 14.91 | 12.67 | 13.77 |
| | Z ₂ | 13.50 | 14.71 | 12.30 | 13.50 | 11.74 | 13.02 | 10.47 | 11.74 | 15.73 | 17.07 | 14.40 | 15.73 | 13.72 | 15.21 | 12.22 | 13.72 |
| M ₄ | Z ₁ | 16.87 | 18.43 | 16.39 | 17.23 | 15.32 | 16.98 | 14.81 | 15.70 | 19.49 | 21.20 | 18.93 | 19.88 | 17.89 | 20.00 | 17.29 | 18.39 |
| | Z ₂ | 16.51 | 17.71 | 16.27 | 16.83 | 14.93 | 16.21 | 14.68 | 15.27 | 19.07 | 20.41 | 18.81 | 19.43 | 17.44 | 19.10 | 17.14 | 17.89 |
| N | | 14.24 | 15.32 | 13.53 | | 12.52 | 13.67 | 11.77 | | 16.56 | 17.75 | 15.76 | | 14.63 | 16.01 | 13.75 | 14.24 |
| | | MxN | | | M | MxN | | | M | MxN | | | M | MxN | | | |
| M | M ₁ | 14.59 | 15.43 | 13.81 | 14.61 | 12.89 | 13.78 | 12.06 | 12.91 | 16.94 | 17.87 | 16.06 | 16.95 | 15.06 | 16.10 | 14.09 | 15.08 |
| | M ₂ | 12.18 | 13.20 | 11.52 | 12.30 | 10.34 | 11.42 | 9.64 | 10.47 | 14.26 | 15.39 | 13.52 | 14.39 | 12.08 | 13.34 | 11.26 | 12.22 |
| | M ₃ | 13.50 | 14.59 | 12.48 | 13.52 | 11.74 | 12.89 | 10.66 | 11.76 | 15.77 | 16.93 | 14.59 | 15.76 | 13.72 | 15.06 | 12.45 | 13.74 |
| | M ₄ | 16.69 | 18.07 | 16.33 | 17.03 | 15.13 | 16.59 | 14.74 | 15.49 | 19.28 | 20.80 | 18.87 | 19.65 | 17.67 | 19.55 | 17.22 | 18.14 |
| | | NxZ | | | Z | NxZ | | | Z | NxZ | | | Z | NxZ | | | |
| Z | Z ₁ | 9.80 | 10.69 | 9.18 | 9.89 | 8.96 | 9.22 | 8.77 | 8.98 | 14.38 | 15.46 | 13.62 | 14.49 | 12.67 | 13.82 | 11.87 | 12.79 |
| | Z ₂ | 9.58 | 10.47 | 9.04 | 9.69 | 8.84 | 9.10 | 8.71 | 8.89 | 14.11 | 15.19 | 13.44 | 14.25 | 12.38 | 13.53 | 11.68 | 12.53 |
| Control | | 4.90 | | | | 4.85 | | | | 9.42 | | | | 9.80 | | | |
| | | S.Em ± | | CD at 5 % | | S.Em ± | | CD at 5 % | | S.Em ± | | CD at 5 % | | S.Em ± | | CD at 5 % | |
| M | | 0.13 | | 0.45 | | 0.15 | | 0.54 | | 0.22 | | 0.77 | | 0.16 | | 0.54 | |
| N | | 0.11 | | 0.32 | | 0.07 | | 0.21 | | 0.20 | | 0.58 | | 0.19 | | 0.56 | |
| Z | | 0.09 | | NS | | 0.09 | | NS | | 0.15 | | NS | | 0.10 | | NS | |
| M x N | | 0.21 | | NS | | 0.14 | | NS | | 0.39 | | NS | | 0.38 | | NS | |
| M x Z | | 0.17 | | NS | | 0.18 | | NS | | 0.29 | | NS | | 0.21 | | NS | |
| N x Z | | 0.15 | | NS | | 0.15 | | NS | | 0.25 | | NS | | 0.18 | | NS | |
| M x N x Z | | 0.30 | | NS | | 0.31 | | NS | | 0.50 | | NS | | 0.36 | | NS | |
| Control vs Rest | | 0.48 | | 0.83 | | 0.57 | | 0.98 | | 0.81 | | 1.41 | | 0.58 | | 1.00 | |

NOTE:

NS : Non significant

Main plot : Soil nitrogen management (M)

Sub plot : Foliar spray of nano nitrogen (N)

Sub-sub plot : Foliar spray of nano zinc (Z)

M₁ : 100 % RDF (ZnSO₄.7H₂O @ 25 kg ha⁻¹)

N₁ : FS of nano N @ 2000 ppm

Z₁ : FS of nano Zn @ 2000 ppm

M₂ : 75 % RDN

N₂ : FS of nano N @ 4000 ppm

Z₂ : FS of nano Zn @ 3000 ppm

M₃ : 100 % RDN M₄ : 125 % RDN

N₃ : FS of nano N @ 6000 ppm

Table 4: Total dry matter production (g hill⁻¹) at flowering and harvest stages of paddy as influenced by different levels of nitrogen along with foliar spray of nano nitrogen and nano zinc

| MxNxZ | | Panicle initiation | | | | | | | | At harvest | | | | | | | |
|-----------------|----------------|-----------------------------|----------------|----------------|--------------|----------------|----------------|----------------|--------------|-----------------------------|----------------|----------------|--------------|----------------|----------------|----------------|--------------|
| | | Rabi (Pooled 2021 and 2022) | | | | Kharif -2021 | | | | Rabi (Pooled 2021 and 2022) | | | | Kharif -2021 | | | |
| | | N ₁ | N ₂ | N ₃ | MxZ | N ₁ | N ₂ | N ₃ | MxZ | N ₁ | N ₂ | N ₃ | MxZ | N ₁ | N ₂ | N ₃ | MxZ |
| M ₁ | Z ₁ | 25.79 | 27.02 | 24.60 | 25.80 | 23.47 | 24.59 | 22.39 | 23.48 | 64.94 | 68.06 | 61.95 | 64.98 | 61.03 | 63.96 | 58.23 | 61.07 |
| | Z ₂ | 25.18 | 26.37 | 25.57 | 25.71 | 22.92 | 24.00 | 22.28 | 23.06 | 63.42 | 66.41 | 64.39 | 64.74 | 59.61 | 62.42 | 60.52 | 60.85 |
| M ₂ | Z ₁ | 22.71 | 23.30 | 22.71 | 22.75 | 20.31 | 20.83 | 20.30 | 20.34 | 59.27 | 60.79 | 59.26 | 59.37 | 55.66 | 57.09 | 55.66 | 55.76 |
| | Z ₂ | 22.47 | 22.66 | 22.24 | 22.62 | 20.09 | 20.26 | 19.89 | 20.22 | 58.65 | 59.14 | 58.04 | 59.01 | 55.08 | 55.54 | 54.51 | 55.43 |
| M ₃ | Z ₁ | 25.29 | 26.89 | 23.73 | 25.31 | 23.02 | 24.48 | 21.60 | 23.03 | 63.70 | 67.73 | 59.77 | 63.73 | 59.25 | 63.00 | 55.59 | 59.28 |
| | Z ₂ | 24.63 | 26.45 | 23.41 | 24.83 | 22.41 | 24.07 | 21.31 | 22.60 | 62.02 | 66.62 | 58.96 | 62.53 | 57.69 | 61.97 | 54.84 | 58.17 |
| M ₄ | Z ₁ | 27.43 | 28.78 | 27.09 | 27.77 | 23.90 | 25.08 | 23.61 | 24.19 | 69.73 | 73.18 | 68.89 | 70.60 | 64.24 | 67.41 | 63.46 | 65.04 |
| | Z ₂ | 26.62 | 28.63 | 26.78 | 27.34 | 23.19 | 24.94 | 23.33 | 23.82 | 67.69 | 72.80 | 68.09 | 69.52 | 62.36 | 67.06 | 62.72 | 64.05 |
| N | | 25.02 | 26.26 | 24.52 | | 22.41 | 23.53 | 21.84 | | 63.68 | 66.84 | 62.42 | | 59.37 | 62.31 | 58.19 | |
| | | MxN | | | M | MxN | | | M | MxN | | | M | MxN | | | M |
| M | M ₁ | 25.48 | 26.70 | 25.08 | 25.76 | 23.19 | 24.30 | 22.33 | 23.27 | 64.18 | 67.23 | 63.17 | 64.86 | 60.32 | 63.19 | 59.37 | 60.96 |
| | M ₂ | 22.59 | 22.98 | 22.48 | 22.68 | 20.20 | 20.55 | 20.10 | 20.28 | 58.96 | 59.96 | 58.65 | 59.19 | 55.37 | 56.32 | 55.09 | 55.59 |
| | M ₃ | 24.96 | 26.67 | 23.57 | 25.07 | 22.72 | 24.27 | 21.45 | 22.81 | 62.86 | 67.17 | 59.36 | 63.13 | 58.47 | 62.48 | 55.22 | 58.72 |
| | M ₄ | 27.02 | 28.70 | 26.93 | 27.55 | 23.55 | 25.01 | 23.47 | 24.01 | 68.71 | 72.99 | 68.49 | 70.06 | 63.30 | 67.24 | 63.09 | 64.54 |
| | | NxZ | | | Z | NxZ | | | Z | NxZ | | | Z | NxZ | | | Z |
| Z | Z ₁ | 25.30 | 26.50 | 24.42 | 25.41 | 22.67 | 23.74 | 21.87 | 22.76 | 64.41 | 67.44 | 62.16 | 64.67 | 60.05 | 62.87 | 57.95 | 60.29 |
| | Z ₂ | 24.73 | 26.03 | 24.62 | 25.12 | 22.16 | 23.32 | 21.81 | 22.43 | 62.94 | 66.24 | 62.67 | 63.95 | 58.68 | 61.75 | 58.44 | 59.62 |
| Control | | 17.94 | | | | 18.46 | | | | 47.33 | | | | 47.25 | | | |
| | | S.Em ± | | CD at 5 % | | S.Em ± | | CD at 5 % | | S.Em ± | | CD at 5 % | | S.Em ± | | CD at 5 % | |
| M | | 0.23 | | 0.81 | | 0.34 | | 1.16 | | 0.67 | | 2.33 | | 0.51 | | 1.78 | |
| N | | 0.34 | | 1.02 | | 0.23 | | 0.70 | | 0.66 | | 1.98 | | 0.68 | | 2.03 | |
| Z | | 0.28 | | NS | | 0.19 | | NS | | 0.64 | | NS | | 0.55 | | NS | |
| M x N | | 0.68 | | NS | | 0.47 | | NS | | 1.32 | | NS | | 1.35 | | NS | |
| M x Z | | 0.57 | | NS | | 0.37 | | NS | | 1.28 | | NS | | 1.10 | | NS | |
| N x Z | | 0.49 | | NS | | 0.32 | | NS | | 1.11 | | NS | | 0.95 | | NS | |
| M x N x Z | | 0.98 | | NS | | 0.65 | | NS | | 2.21 | | NS | | 1.91 | | NS | |
| Control vs Rest | | 0.86 | | 1.48 | | 1.24 | | 2.14 | | 2.48 | | 4.28 | | 1.89 | | 3.26 | |

NOTE:

NS : Non significant

Main plot : Soil nitrogen management (M)

Sub plot : Foliar spray of nano nitrogen (N)

Sub-sub plot : Foliar spray of nano zinc (Z)

M₁ : 100 % RDF (ZnSO₄.7H₂O @ 25 kg ha⁻¹)

N₁ : FS of nano N @ 2000 ppm

Z₁ : FS of nano Zn @ 2000 ppm

M₂ : 75 % RDN

N₂ : FS of nano N @ 4000 ppm

Z₂ : FS of nano Zn @ 3000 ppm

M₃ : 100 % RDN

N₃ : FS of nano N @ 6000 ppm

M₄ : 125 % RDN

Table 5: Leaf chlorophyll content (SPAD) at active tillering, panicle initiation and flowering stages of paddy as influenced by different levels of nitrogen along with foliar spray of nano nitrogen and nano zinc

| MxNxZ | | Active tillering | | | | | | | | Panicle initiation | | | | | | | | Flowering | | | | | | | | | | |
|-----------------|----------------|-----------------------------|----------------|----------------|--------------|----------------|----------------|----------------|--------------|-----------------------------|----------------|----------------|--------------|----------------|----------------|----------------|--------------|-----------------------------|----------------|----------------|--------------|----------------|----------------|----------------|--------------|---|--|--|
| | | Rabi (Pooled 2021 and 2022) | | | | Kharif -2021 | | | | Rabi (Pooled 2021 and 2022) | | | | Kharif -2021 | | | | Rabi (Pooled 2021 and 2022) | | | | Kharif -2021 | | | | | | |
| | | N ₁ | N ₂ | N ₃ | MxZ | N ₁ | N ₂ | N ₃ | MxZ | N ₁ | N ₂ | N ₃ | MxZ | N ₁ | N ₂ | N ₃ | MxZ | N ₁ | N ₂ | N ₃ | MxZ | N ₁ | N ₂ | N ₃ | MxZ | | | |
| M ₁ | Z ₁ | 30.07 | 30.98 | 29.53 | 30.19 | 27.42 | 28.31 | 26.89 | 27.54 | 41.15 | 42.54 | 40.71 | 41.46 | 38.28 | 39.44 | 37.58 | 38.43 | 44.07 | 45.59 | 43.70 | 44.45 | 40.58 | 41.90 | 39.80 | 40.76 | | | |
| | Z ₂ | 29.60 | 30.60 | 29.38 | 29.86 | 26.97 | 27.94 | 26.75 | 27.22 | 40.55 | 41.99 | 40.33 | 40.96 | 37.68 | 38.96 | 37.40 | 38.01 | 43.45 | 45.03 | 43.32 | 43.93 | 39.91 | 41.35 | 39.59 | 40.28 | | | |
| M ₂ | Z ₁ | 28.16 | 28.62 | 27.60 | 28.13 | 25.47 | 25.91 | 24.92 | 25.43 | 38.60 | 39.43 | 37.77 | 38.60 | 35.85 | 36.43 | 35.13 | 35.81 | 41.43 | 42.33 | 40.62 | 41.46 | 38.46 | 39.13 | 37.63 | 38.40 | | | |
| | Z ₂ | 27.84 | 28.45 | 27.54 | 27.94 | 25.16 | 25.74 | 24.86 | 25.25 | 38.35 | 39.22 | 37.40 | 38.33 | 35.44 | 36.21 | 35.06 | 35.57 | 41.16 | 42.11 | 40.25 | 41.18 | 37.98 | 38.87 | 37.54 | 38.13 | | | |
| M ₃ | Z ₁ | 29.79 | 30.62 | 28.91 | 29.77 | 27.75 | 28.56 | 26.89 | 27.73 | 40.75 | 41.96 | 39.93 | 40.88 | 37.92 | 38.98 | 36.80 | 37.90 | 43.70 | 45.00 | 42.89 | 43.86 | 40.51 | 41.69 | 39.27 | 40.49 | | | |
| | Z ₂ | 29.49 | 30.20 | 28.81 | 29.50 | 27.45 | 28.14 | 26.79 | 27.46 | 40.41 | 41.45 | 39.80 | 40.55 | 37.53 | 38.44 | 36.67 | 37.55 | 43.35 | 44.47 | 42.76 | 43.53 | 40.08 | 41.09 | 39.11 | 40.09 | | | |
| M ₄ | Z ₁ | 31.65 | 32.04 | 31.27 | 31.65 | 29.26 | 29.64 | 28.88 | 29.26 | 43.58 | 44.24 | 43.25 | 43.69 | 40.30 | 40.79 | 39.80 | 40.30 | 46.62 | 47.40 | 46.38 | 46.80 | 42.72 | 43.27 | 42.17 | 42.72 | | | |
| | Z ₂ | 31.46 | 31.86 | 31.16 | 31.49 | 29.07 | 29.46 | 28.78 | 29.10 | 43.40 | 44.03 | 43.04 | 43.49 | 40.05 | 40.56 | 39.66 | 40.09 | 46.43 | 47.17 | 46.16 | 46.59 | 42.44 | 43.01 | 42.02 | 42.49 | | | |
| N | | 29.76 | 30.42 | 29.27 | | 27.32 | 27.96 | 26.85 | | 40.85 | 41.86 | 40.28 | | 37.88 | 38.73 | 37.26 | | 43.78 | 44.89 | 43.26 | | 40.34 | 41.29 | 39.64 | | | | |
| | | MxN | | | M | | | MxN | | | M | | | MxN | | | M | | | MxN | | | M | | | M | | |
| M | M ₁ | 29.84 | 30.79 | 29.45 | 30.03 | 27.19 | 28.12 | 26.82 | 27.38 | 40.85 | 42.26 | 40.52 | 41.21 | 37.98 | 39.20 | 37.49 | 38.22 | 43.76 | 45.31 | 43.51 | 44.19 | 40.25 | 41.62 | 39.69 | 40.52 | | | |
| | M ₂ | 28.00 | 28.53 | 27.57 | 28.04 | 25.31 | 25.83 | 24.89 | 25.34 | 38.48 | 39.33 | 37.59 | 38.46 | 35.65 | 36.32 | 35.10 | 35.69 | 41.30 | 42.22 | 40.43 | 41.32 | 38.22 | 39.00 | 37.59 | 38.27 | | | |
| | M ₃ | 29.64 | 30.41 | 28.86 | 29.64 | 27.60 | 28.35 | 26.84 | 27.60 | 40.58 | 41.71 | 39.87 | 40.72 | 37.73 | 38.71 | 36.74 | 37.72 | 43.52 | 44.74 | 42.82 | 43.69 | 40.29 | 41.39 | 39.19 | 40.29 | | | |
| | M ₄ | 31.56 | 31.95 | 31.21 | 31.57 | 29.17 | 29.55 | 28.83 | 29.18 | 43.49 | 44.13 | 43.15 | 43.59 | 40.17 | 40.67 | 39.73 | 40.19 | 46.53 | 47.29 | 46.27 | 46.69 | 42.58 | 43.14 | 42.09 | 42.60 | | | |
| | | NxZ | | | Z | | | NxZ | | | Z | | | NxZ | | | Z | | | NxZ | | | Z | | | Z | | |
| Z | Z ₁ | 29.92 | 30.57 | 29.33 | 29.94 | 27.47 | 28.10 | 26.90 | 27.49 | 41.02 | 42.04 | 40.41 | 41.16 | 38.09 | 38.91 | 37.33 | 38.11 | 43.96 | 45.08 | 43.40 | 44.14 | 40.57 | 41.50 | 39.71 | 40.59 | | | |
| | Z ₂ | 29.60 | 30.28 | 29.22 | 29.70 | 27.16 | 27.82 | 26.79 | 27.26 | 40.68 | 41.67 | 40.14 | 40.83 | 37.68 | 38.54 | 37.20 | 37.80 | 43.60 | 44.70 | 43.12 | 43.80 | 40.10 | 41.08 | 39.57 | 40.25 | | | |
| Control | | 25.07 | | | | 24.86 | | | | 31.06 | | | | 29.38 | | | | 35.14 | | | | 33.44 | | | | | | |
| | | S.Em ± | | CD at 5 % | | S.Em ± | | CD at 5 % | | S.Em ± | | CD at 5 % | | S.Em ± | | CD at 5 % | | S.Em ± | | CD at 5 % | | S.Em ± | | CD at 5 % | | | | |
| M | | 0.40 | | 1.39 | | 0.28 | | 0.98 | | 0.58 | | 2.01 | | 0.38 | | 1.30 | | 0.36 | | 1.23 | | 0.25 | | 0.85 | | | | |
| N | | 0.25 | | 0.75 | | 0.19 | | 0.58 | | 0.36 | | 1.00 | | 0.28 | | 0.82 | | 0.31 | | 0.94 | | 0.33 | | 0.90 | | | | |
| Z | | 0.26 | | NS | | 0.29 | | NS | | 0.40 | | NS | | 0.35 | | NS | | 0.43 | | NS | | 0.38 | | NS | | | | |
| M x N | | 0.50 | | NS | | 0.39 | | NS | | 0.72 | | NS | | 0.76 | | NS | | 0.63 | | NS | | 0.85 | | NS | | | | |
| M x Z | | 0.53 | | NS | | 0.58 | | NS | | 0.80 | | NS | | 0.70 | | NS | | 0.85 | | NS | | 0.76 | | NS | | | | |
| N x Z | | 0.46 | | NS | | 0.50 | | NS | | 0.69 | | NS | | 0.60 | | NS | | 0.74 | | NS | | 0.66 | | NS | | | | |
| M x N x Z | | 0.92 | | NS | | 1.01 | | NS | | 1.38 | | NS | | 1.21 | | NS | | 1.47 | | NS | | 1.32 | | NS | | | | |
| Control vs Rest | | 1.47 | | 2.55 | | 1.04 | | 1.79 | | 2.13 | | 3.69 | | 1.38 | | 2.39 | | 1.31 | | 2.27 | | 0.90 | | 1.56 | | | | |

NOTE:

NS : Non significant

Main plot : Soil nitrogen management (M) M₁ : 100 % RDF (ZnSO₄.7H₂O @ 25 kg ha⁻¹) M₂ : 75 % RDN M₃ : 100 % RDN M₄ : 125 % RDN
 Sub plot : Foliar spray of nano nitrogen (N) N₁ : FS of nano N @ 2000 ppm N₂ : FS of nano N @ 4000 ppm N₃ : FS of nano N @ 6000 ppm
 Sub-sub plot : Foliar spray of nano zinc (Z) Z₁ : FS of nano Zn @ 2000 ppm Z₂ : FS of nano Zn @ 3000 ppm

Table 6: Normalized Difference Vegetation Index (NDVI) at active tillering, panicle initiation and flowering stages of paddy as influenced by different levels of nitrogen along with foliar application of nano nitrogen and nano zinc

| MxNxZ | | Active tillering | | | | | | | | Panicle initiation | | | | | | | | Flowering | | | | | | | |
|-----------------|----------------|-----------------------------|----------------|----------------|-------------|----------------|----------------|----------------|-------------|-----------------------------|----------------|----------------|-------------|----------------|----------------|----------------|-------------|-----------------------------|----------------|----------------|-------------|----------------|----------------|----------------|-------------|
| | | Rabi (Pooled 2021 and 2022) | | | | Kharif -2021 | | | | Rabi (Pooled 2021 and 2022) | | | | Kharif -2021 | | | | Rabi (Pooled 2021 and 2022) | | | | Kharif -2021 | | | |
| | | N ₁ | N ₂ | N ₃ | MxZ | N ₁ | N ₂ | N ₃ | MxZ | N ₁ | N ₂ | N ₃ | MxZ | N ₁ | N ₂ | N ₃ | MxZ | N ₁ | N ₂ | N ₃ | MxZ | N ₁ | N ₂ | N ₃ | MxZ |
| M ₁ | Z ₁ | 0.51 | 0.53 | 0.49 | 0.51 | 0.47 | 0.49 | 0.45 | 0.47 | 0.69 | 0.73 | 0.66 | 0.69 | 0.63 | 0.67 | 0.61 | 0.63 | 0.81 | 0.84 | 0.78 | 0.81 | 0.75 | 0.79 | 0.72 | 0.75 |
| | Z ₂ | 0.49 | 0.52 | 0.48 | 0.50 | 0.45 | 0.48 | 0.45 | 0.46 | 0.67 | 0.70 | 0.65 | 0.67 | 0.61 | 0.64 | 0.60 | 0.62 | 0.79 | 0.82 | 0.77 | 0.80 | 0.73 | 0.76 | 0.71 | 0.74 |
| M ₂ | Z ₁ | 0.42 | 0.43 | 0.40 | 0.42 | 0.38 | 0.39 | 0.37 | 0.38 | 0.59 | 0.61 | 0.57 | 0.59 | 0.51 | 0.54 | 0.50 | 0.52 | 0.73 | 0.76 | 0.73 | 0.74 | 0.62 | 0.64 | 0.60 | 0.62 |
| | Z ₂ | 0.41 | 0.43 | 0.39 | 0.41 | 0.37 | 0.39 | 0.36 | 0.37 | 0.58 | 0.60 | 0.56 | 0.58 | 0.50 | 0.53 | 0.49 | 0.51 | 0.72 | 0.75 | 0.71 | 0.73 | 0.61 | 0.64 | 0.59 | 0.61 |
| M ₃ | Z ₁ | 0.47 | 0.48 | 0.46 | 0.47 | 0.43 | 0.44 | 0.42 | 0.43 | 0.65 | 0.67 | 0.64 | 0.65 | 0.58 | 0.60 | 0.57 | 0.59 | 0.77 | 0.82 | 0.75 | 0.78 | 0.70 | 0.71 | 0.68 | 0.70 |
| | Z ₂ | 0.46 | 0.47 | 0.46 | 0.46 | 0.42 | 0.43 | 0.42 | 0.42 | 0.63 | 0.65 | 0.64 | 0.64 | 0.57 | 0.58 | 0.58 | 0.58 | 0.78 | 0.77 | 0.74 | 0.77 | 0.67 | 0.70 | 0.67 | 0.68 |
| M ₄ | Z ₁ | 0.54 | 0.56 | 0.52 | 0.54 | 0.49 | 0.52 | 0.48 | 0.50 | 0.73 | 0.76 | 0.70 | 0.73 | 0.68 | 0.71 | 0.66 | 0.68 | 0.86 | 0.88 | 0.85 | 0.86 | 0.82 | 0.86 | 0.80 | 0.83 |
| | Z ₂ | 0.53 | 0.55 | 0.51 | 0.53 | 0.49 | 0.51 | 0.47 | 0.49 | 0.72 | 0.74 | 0.69 | 0.72 | 0.67 | 0.70 | 0.65 | 0.67 | 0.84 | 0.87 | 0.82 | 0.84 | 0.80 | 0.84 | 0.78 | 0.81 |
| N | | 0.47 | 0.50 | 0.46 | | 0.44 | 0.46 | 0.43 | | 0.65 | 0.68 | 0.64 | | 0.59 | 0.62 | 0.58 | | 0.78 | 0.81 | 0.76 | | 0.70 | 0.74 | 0.68 | |
| | | MxN | | M | | MxN | | M | | MxN | | M | | MxN | | M | | MxN | | M | | MxN | | M | |
| M | M ₁ | 0.50 | 0.52 | 0.48 | 0.50 | 0.46 | 0.48 | 0.45 | 0.46 | 0.68 | 0.72 | 0.65 | 0.68 | 0.62 | 0.65 | 0.60 | 0.63 | 0.80 | 0.83 | 0.78 | 0.80 | 0.74 | 0.78 | 0.72 | 0.75 |
| | M ₂ | 0.41 | 0.43 | 0.40 | 0.41 | 0.38 | 0.39 | 0.37 | 0.38 | 0.58 | 0.60 | 0.57 | 0.58 | 0.51 | 0.53 | 0.50 | 0.51 | 0.73 | 0.75 | 0.72 | 0.73 | 0.61 | 0.64 | 0.60 | 0.62 |
| | M ₃ | 0.46 | 0.48 | 0.46 | 0.47 | 0.42 | 0.43 | 0.42 | 0.43 | 0.64 | 0.66 | 0.64 | 0.65 | 0.58 | 0.59 | 0.57 | 0.58 | 0.77 | 0.79 | 0.75 | 0.77 | 0.69 | 0.70 | 0.68 | 0.69 |
| | M ₄ | 0.53 | 0.55 | 0.51 | 0.53 | 0.49 | 0.51 | 0.48 | 0.49 | 0.72 | 0.75 | 0.70 | 0.72 | 0.67 | 0.70 | 0.65 | 0.68 | 0.85 | 0.88 | 0.83 | 0.85 | 0.82 | 0.85 | 0.79 | 0.82 |
| | | NxZ | | Z | | NxZ | | Z | | NxZ | | Z | | NxZ | | Z | | NxZ | | Z | | NxZ | | Z | |
| Z | Z ₁ | 0.48 | 0.50 | 0.47 | 0.48 | 0.44 | 0.46 | 0.43 | 0.44 | 0.66 | 0.69 | 0.64 | 0.67 | 0.60 | 0.63 | 0.58 | 0.60 | 0.79 | 0.82 | 0.78 | 0.80 | 0.72 | 0.75 | 0.70 | 0.72 |
| | Z ₂ | 0.47 | 0.49 | 0.46 | 0.47 | 0.43 | 0.45 | 0.43 | 0.44 | 0.65 | 0.67 | 0.64 | 0.65 | 0.59 | 0.61 | 0.58 | 0.59 | 0.79 | 0.80 | 0.76 | 0.78 | 0.70 | 0.73 | 0.69 | 0.71 |
| Control | | 0.28 | | | | 0.26 | | | | 0.43 | | | | 0.36 | | | | 0.57 | | | | 0.51 | | | |
| | | S.Em ± | | CD at 5 % | | S.Em ± | | CD at 5 % | | S.Em ± | | CD at 5 % | | S.Em ± | | CD at 5 % | | S.Em ± | | CD at 5 % | | S.Em ± | | CD at 5 % | |
| M | | 0.01 | | 0.02 | | 0.01 | | 0.02 | | 0.01 | | 0.03 | | 0.00 | | 0.02 | | 0.01 | | 0.02 | | 0.01 | | 0.03 | |
| N | | 0.01 | | 0.02 | | 0.00 | | 0.01 | | 0.01 | | 0.02 | | 0.01 | | 0.02 | | 0.01 | | 0.03 | | 0.01 | | 0.03 | |
| Z | | 0.00 | | NS | | 0.00 | | NS | | 0.01 | | NS | | 0.01 | | NS | | 0.01 | | NS | | 0.01 | | NS | |
| M x N | | 0.01 | | NS | | 0.01 | | NS | | 0.02 | | NS | | 0.01 | | NS | | 0.02 | | NS | | 0.02 | | NS | |
| M x Z | | 0.01 | | NS | | 0.01 | | NS | | 0.01 | | NS | | 0.01 | | NS | | 0.01 | | NS | | 0.01 | | NS | |
| N x Z | | 0.01 | | NS | | 0.01 | | NS | | 0.01 | | NS | | 0.01 | | NS | | 0.01 | | NS | | 0.01 | | NS | |
| M x N x Z | | 0.02 | | NS | | 0.01 | | NS | | 0.02 | | NS | | 0.02 | | NS | | 0.02 | | NS | | 0.02 | | NS | |
| Control vs Rest | | 0.02 | | 0.03 | | 0.02 | | 0.04 | | 0.03 | | 0.05 | | 0.02 | | 0.03 | | 0.02 | | 0.04 | | 0.03 | | 0.05 | |

NOTE:

NS : Non significant

Main plot : Soil nitrogen management (M)

Sub plot : Foliar spray of nano nitrogen (N)

Sub-sub plot : Foliar spray of nano zinc (Z)

M₁ : 100 % RDF (ZnSO₄.7H₂O @ 25 kg ha⁻¹)

N₁ : FS of nano N @ 2000 ppm

Z₁ : FS of nano Zn @ 2000 ppm

M₂ : 75 % RDN

N₂ : FS of nano N @ 4000 ppm

Z₂ : FS of nano Zn @ 3000 ppm

M₃ : 100 % RDN M₄ : 125 % RDN

N₃ : FS of nano N @ 6000 ppm

Table 7: Grain yield and straw yield of paddy as influenced by different levels of nitrogen with foliar spray of nano nitrogen and nano zinc during *rabi* (pooled 2021 and 2022) and *kharif* (2021)

| MxNxZ | | Grain yield (kg ha ⁻¹) | | | | | | | | Straw yield (kg ha ⁻¹) | | | | | | | |
|-----------------|----------------|------------------------------------|----------------|----------------|-------------|---------------------|----------------|----------------|-------------|------------------------------------|----------------|----------------|-------------|---------------------|----------------|----------------|-------------|
| | | <i>Rabi</i> (Pooled 2021 and 2022) | | | | <i>Kharif</i> -2021 | | | | <i>Rabi</i> (Pooled 2021 and 2022) | | | | <i>Kharif</i> -2021 | | | |
| | | N ₁ | N ₂ | N ₃ | MxZ | N ₁ | N ₂ | N ₃ | MxZ | N ₁ | N ₂ | N ₃ | MxZ | N ₁ | N ₂ | N ₃ | MxZ |
| M ₁ | Z ₁ | 5480 | 5743 | 5377 | 5533 | 5213 | 5463 | 5115 | 5264 | 6684 | 7003 | 6559 | 6749 | 6412 | 6720 | 6292 | 6474 |
| | Z ₂ | 5352 | 5604 | 5352 | 5436 | 5091 | 5331 | 5091 | 5171 | 6529 | 6834 | 6528 | 6630 | 6262 | 6557 | 6262 | 6360 |
| M ₂ | Z ₁ | 5246 | 5380 | 5137 | 5254 | 4979 | 5107 | 4877 | 4988 | 6400 | 6563 | 6269 | 6411 | 6175 | 6333 | 6047 | 6185 |
| | Z ₂ | 5191 | 5234 | 5051 | 5159 | 4927 | 4969 | 4794 | 4897 | 6334 | 6386 | 6164 | 6295 | 6110 | 6161 | 5945 | 6072 |
| M ₃ | Z ₁ | 5375 | 5716 | 5188 | 5426 | 5113 | 5437 | 4935 | 5162 | 6557 | 6969 | 6330 | 6619 | 6290 | 6688 | 6070 | 6349 |
| | Z ₂ | 5234 | 5622 | 5118 | 5325 | 4979 | 5348 | 4868 | 5065 | 6386 | 6856 | 6245 | 6496 | 6124 | 6578 | 5988 | 6230 |
| M ₄ | Z ₁ | 5580 | 5856 | 5670 | 5702 | 5330 | 5594 | 5416 | 5447 | 6742 | 7074 | 6850 | 6889 | 6503 | 6824 | 6608 | 6645 |
| | Z ₂ | 5417 | 5825 | 5604 | 5615 | 5174 | 5564 | 5353 | 5364 | 6544 | 7037 | 6770 | 6784 | 6312 | 6789 | 6531 | 6544 |
| N | | 5359 | 5623 | 5312 | | 5101 | 5352 | 5056 | | 6522 | 6840 | 6465 | | 6273 | 6581 | 6218 | |
| | | MxN | | | M | MxN | | | M | MxN | | | M | MxN | | | M |
| M | M ₁ | 5416 | 5674 | 5364 | 5485 | 5152 | 5397 | 5103 | 5217 | 6606 | 6918 | 6544 | 6690 | 6337 | 6638 | 6277 | 6417 |
| | M ₂ | 5218 | 5307 | 5094 | 5206 | 4953 | 5038 | 4836 | 4942 | 6367 | 6475 | 6217 | 6353 | 6142 | 6247 | 5996 | 6129 |
| | M ₃ | 5305 | 5669 | 5153 | 5375 | 5046 | 5393 | 4901 | 5113 | 6472 | 6913 | 6288 | 6557 | 6207 | 6633 | 6029 | 6290 |
| | M ₄ | 5499 | 5841 | 5637 | 5659 | 5252 | 5579 | 5385 | 5405 | 6643 | 7056 | 6810 | 6836 | 6408 | 6807 | 6569 | 6595 |
| | | NxZ | | | Z | NxZ | | | Z | NxZ | | | Z | NxZ | | | Z |
| Z | Z ₁ | 5420 | 5674 | 5343 | 5479 | 5159 | 5400 | 5086 | 5215 | 6596 | 6902 | 6502 | 6667 | 6345 | 6641 | 6254 | 6413 |
| | Z ₂ | 5298 | 5571 | 5281 | 5384 | 5043 | 5303 | 5027 | 5124 | 6448 | 6778 | 6427 | 6551 | 6202 | 6521 | 6181 | 6302 |
| Control | | 3688 | | | | 3668 | | | | 4588 | | | | 4569 | | | |
| | | S.Em ± | | CD at 5 % | | S.Em ± | | CD at 5 % | | S.Em ± | | CD at 5 % | | S.Em ± | | CD at 5 % | |
| M | | 81.53 | | 293.53 | | 82.89 | | 295.35 | | 90.08 | | 311.72 | | 91.25 | | 320.83 | |
| N | | 58.37 | | 175.00 | | 55.82 | | 167.36 | | 82.76 | | 248.11 | | 68.65 | | 205.83 | |
| Z | | 51.43 | | NS | | 52.28 | | NS | | 61.71 | | NS | | 63.46 | | NS | |
| M x N | | 116.75 | | NS | | 111.65 | | NS | | 165.51 | | NS | | 137.31 | | NS | |
| M x Z | | 102.86 | | NS | | 104.56 | | NS | | 123.42 | | NS | | 126.92 | | NS | |
| N x Z | | 89.08 | | NS | | 90.55 | | NS | | 106.88 | | NS | | 109.92 | | NS | |
| M x N x Z | | 178.16 | | NS | | 181.11 | | NS | | 213.77 | | NS | | 219.83 | | NS | |
| Control vs Rest | | 262.82 | | 454.74 | | 164.95 | | 285.40 | | 330.98 | | 572.66 | | 192.00 | | 332.20 | |

NOTE:

NS : Non significant

Main plot : Soil nitrogen management (M)

Sub plot : Foliar spray of nano nitrogen (N)

Sub-sub plot : Foliar spray of nano zinc (Z)

M₁ : 100 % RDF (ZnSO₄.7H₂O @ 25 kg ha⁻¹)

N₁ : FS of nano N @ 2000 ppm

Z₁ : FS of nano Zn @ 2000 ppm

M₂ : 75 % RDN

N₂ : FS of nano N @ 4000 ppm

Z₂ : FS of nano Zn @ 3000 ppm

M₃ : 100 % RDN

N₃ : FS of nano N @ 6000 ppm

M₄ : 125 % RDN

