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Effect of Nano-urea on Growth, Productivity and Economics of Transplanted Rice

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Abstract

A field experiment was conducted during July to November of 2021 to assess the effect of nano-urea on growth and productivity of rice at ICAR-Indian Institute of Rice Research, Hyderabad, Telangana State, India. The experiment was laid out in randomized complete block design consisting eight treatments viz., Recommended dose of nitrogen (RDN) through urea (T_1), 50% of RDN (urea)+two foliar sprays of nano-urea @ 0.2% at Active tillering (AT) and Panicle initiation (PI) stages (T_2), 75% of RDN+two foliar sprays of nano-urea @ 0.2% at AT and PI (T_3), 50% of RDN+two foliar sprays of nano-urea @ 0.4% at (AT and PI) (T_4), 75% of RDN+two foliar sprays of nano-urea @ 0.4% at AT and PI (T_5), 25% of RDN+Four foliar sprays of nano-urea @ 0.2% at 20,33,50 and 65 DAT (T_6), 25% of RDN+Four foliar sprays of nano-urea @ 0.4% 20,33,50 and 65 DAT (T_7) and control (no fertilizer application) (T_8). Results showed that foliar spray of nano-urea resulted in higher plant height (120.1 cm), tillers number m^{-2} (265) and dry matter accumulation (741.9 kg ha^{-1}). Yield attributes viz., panicle number m^{-2}, number of grains $panicle^{-1}$, number of filled grains $panicle^{-1}$ were significantly influenced by the application of nano-urea. The highest grain yield (5.39 t ha^{-1}) and straw yield (6.73 t ha^{-1}) was recorded with the application of 75% of RDN+two foliar sprays of nano-urea @ 0.4% at AT and PI stages. The application of nano-urea resulted in saving of nitrogen (urea) to an extent of 25%.

Keywords: Nano-urea, nitrogen, nitrogen use efficiency, rice, urea

1. Introduction

Over 90% of the world's rice is produced and consumed in Asia, additionally rice farming is the main livelihood opportunity for more than 200 million households throughout the world, making it one of the most significant crop for human (Tonini and Cabrera, 2011). Ensuring food security along with nutrition, simultaneously sustaining the environment are the major obstacles faced by the Asian nations presently, particularly India, whose population has surpassed 1.4 billion. World-wide, rice is grown over 163 M ha are and India ranks number one globally with about 45 million hectares and with production of 124 million tonnes next to China (Anonymous, 2023). Fertilizer management is the one of the most important agronomic management practices in modern day farming upon which the productivity of the crop is dependent. Among all nutrients, nitrogen is the first and most important nutrient for crop growth and development as it is the major constituent of chlorophyll which helps in photosynthesis (Rathnayaka et al., 2018). Despite previous efforts, the Nitrogen Use Efficiency (NUE) in modern farming system is very low that is only 45-50% (Iqbal et al., 2020) meaning that on a global scale, more than 50% of the N applied to agricultural soils is potentially lost into the environment. One of the major challenges of modern agriculture is to satisfy present and future global food demands efficiently (Calicioglu et al., 2019). Use efficiency of N needs to be improved substantially by increasing the efficiency of agricultural systems and adopting environmentally sound agronomic practices (Zhang et al., 2023), and exploring modern technologies. Nano-fertilizers possess unique features which enhance plants' performance in terms of ultra-high absorption, increase in production, rise in photosynthesis and significant expansion in the leaves surface area (Nongbet et al., 2022; Rautela et al., 2021). Besides, the controlled release of nutrients contributes in preventing eutrophication and pollution of water resources (Guo et al., 2018). Replacement of traditional fertilizer by nano-fertilizer is beneficial as upon application, it releases nutrients into the soil steadily and in a controlled way thus, preventing the water pollution. It would have been very helpful if nano-fertilizers are used for specific crops such as rice to minimize the potential negative effects brought about by the extensive use of conventional chemical fertilizers without compromising production and nutritional benefits. Recently, liquid nano-urea fertilizer is introduced in India which may serve as an alternative to urea fertilizer to improve N use efficiency. It may have the potential to bring down the import of urea fertilizer, subsidy burden to government, reduce the transport, storage costs and usage of urea fertilizer subsequently reduce the cost of nitrogen fertilizer. It was reported that, uptake efficiency of nano-urea is more than 80% compared to prilled urea application (Kumar et al., 2021). When sprayed on the leaves, nano-nutrient formulation enters through stomata through the gas exchange and is assimilated by the plant cells (Abdel-Aziz et al., 2018; Tarafdar et al., 2014). Then it is easily transported via phloem from the source to sink, according to requirements and unused N remained in the plant vacuole and released gradually for plant growth and development. However, efficiency of nano formulation of urea may vary in varied crop, soil, and climatic condition. Also, economics of nano-urea application in rice may differ due to application of the same. Keeping these in views, a study was conducted to assess the effect of nano-urea on growth, productivity, and economics of transplanted rice.

2. Materials and Methods

The present experiment was taken up during the *kharif* season (July to November) of 2021 at research farm of ICAR-IIRR, Hyderabad (17°19'34" N, 78°23'00" E), Telangana state, India, under the southern plateau and hill zone. This zone has extreme weather conditions as during summer exceeds 40°C, while the nights are cool and breezy. The soil was sandy loam in texture, slightly alkaline in reaction, low in available nitrogen and organic carbon, medium in available phosphorus and high in available potassium. The total rainfall during the crop growth period (July to November) was 759.7 mm. The mean standard weekly minimum and maximum temperatures during the of experiment ranged from 14.5 to 25.5°C and 24 to 36°C, respectively. However, mean weekly minimum relative humidity ranged from 88 to 95% while the maximum relative humidity ranged from 49 to 92% during the crop growth period.

The experiment was laid out in randomized complete block design (RCBD) with three replications and 8 treatments viz., Recommended dose of nitrogen (RDN) through urea (T_1), 50% of RDN (urea)+two foliar sprays of nano-urea @ 0.2% at Active tillering (AT) and Panicle initiation (PI) stages (T_2), 75% of RDN (urea)+two foliar sprays of nano-urea @0.2% at (AT and PI) stages (T_3), 50% of RDN+two foliar sprays of nano-urea @ 0.4% at (AT and PI) stages (T_4), 75% of RDN+two foliar sprays of nano-urea @ 0.4% at AT and PI stages (T_5), 25% of RDN+Four foliar sprays of nano-urea @ 0.2% at 20,33,50 and 65 DAT (T_6), 25% of RDN+Four foliar sprays of nano-urea @ 0.4% 20,33,50 and 65 DAT (T_7) and control (no fertilizer application) (T_8). Rice variety "RNR 15048" (Telangana Sona) with seed rate of 30 kg ha^{-1} and spacing 20 cm×10 cm was used in the study.

Pre-germinated seeds were broadcasted thoroughly on the puddled and levelled soil of the wet nursery. The recommended dose of fertilizers for rice i.e., 120:60:60 kg ha^{-1} was applied to the experimental crop. Nitrogen was applied to the plots according to the treatments considering the reduced doses of recommended soil application i.e., RDN through prilled-urea. Liquid nano-urea was applied to the plots treatment-wise. Half of the nitrogen through prilled-urea, full amount of phosphorous was applied as basal prior to transplantation. The remaining amount of nitrogen was applied in two splits active tillering and booting stages. Alternate wetting and drying method of irrigation was followed to meet the water requirement of the crop. One hand weeding was done at 30 DAT to keep the crop free from weeds. The crop was harvested at physiological maturity stage which was judged visually when 95% of panicles turned in to golden colour straw and grain yield were recorded as per treatment wise and reported in t ha^{-1}. The observed data was analysed as per the standard procedure defined by Gomez and Gomez (1984).

3. Results and Discussion

3.1. Effect on crop growth

Plant height of rice did not differ significantly at 30 DAT, but had shown significant difference among the treatments at 60 and 90 DAT(Harvest) (Table 1). Application of 75% RDN+Nano-urea @ 0.4% at 60 and 90 DAT resulted in taller plants (117.7 and 120.1 cm), respectively, which was at par with the application of recommended dose of nitrogen (RDN) through urea (109.7 and 117.9 cm), at both the stages. All the other treatments with the application of 25 and 50% RDN along with 2 and 4 foliar sprays of nano-urea @ 0.2 and 0.4%, recorded similar plant height, which was at par with RDN-urea. The plant height with the application of 75% RDN+Nano-urea @ 0.4% was 16.1 and 15.2% more compared to control at 60 and 90 DAT, respectively. The taller plants of rice were obtained with the application of 75% RDN+2 foliar sprays of nano-urea @ 0.4%, is attributed to the role of N in improving rice growth, internodes elongation, photosynthesis and metabolism and assimilate production ultimately resulted in better crop growth (Benzon et al., 2015). Several other researchers also reported improvement in plant growth due to external application of nano formulations (Mandeh et al., 2012; Song et al., 2013).

The number of tillers per m^2 at 30, 60 and 90 DAT (harvest) were significantly varied with the application of various nitrogen management practices (Table 1). Application of 75% RDN+2 foliar sprays of nano-urea @ 4% at AT and PI stages significantly recorded the higher number of tillers per m^2 of 228, 265 and 240 at 30, 60 and 90 DAT (harvest) respectively, which was at par with the Recommended dose of nitrogen (RDN) through urea, 75% of RDN+two foliar sprays of nano-urea @ 0.2%), 50% of RDN (urea)+two foliar sprays

Table 1: Effect of nano-urea application on growth of rice

Treatments	Plant height (cm)			No. of tillers m^{-2}			Dry matter accumulation ($g\ m^{-2}$)		
	30 DAT	60 DAT	90 DAT (Harvest)	30 DAT	60 DAT	90 DAT (Harvest)	30 DAT	60 DAT	90 DAT (Harvest)
T_1: Recommended dose of N through urea (100% RDN)	60.8	109.7	117.9	227	243	228	145.0	431.9	707.5
T_2: 50% RDN+Two foliar sprays of nano-urea @ 0.2%	59.3	104.7	110.1	206	227	224	127.7	377.7	650.5
T_3: 75% RDN+Two foliar sprays of nano-urea @0.2%	60.1	103.1	115.0	212	240	228	147.6	415.5	704.3
T_4: 50% RDN+Two foliar sprays of nano-urea @0.4%	59.5	101.7	112.0	208	233	224	147.1	419.6	691.1
T_5: 75% RDN+Two foliar sprays of nano-urea @0.4%	62.8	117.7	120.1	228	265	240	158.7	449.5	741.9
T_6: 25% RDN+Four foliar sprays of nano-urea @0.2%	57.3	101.3	108.1	195	229	204	121.6	293.1	610.5
T_7: 25% RDN+Four foliar sprays of nano-urea @0.4%	58.3	105.9	108.4	198	231	213	123.2	324.1	625.3
T_8: Control (no application of fertilizer)	57.0	98.7	101.8	167	206	168	104.2	270.1	580.9
SEm±	1.4	3.0	3.2	9.1	9.5	10.1	7.78	23.9	33.3
CD (p=0.05)	NS	9.0	9.8	27.7	28.9	30.8	23.6	72.5	100.9

of nano-urea @ 0.2% and 50% of RDN+two foliar sprays of nano-urea @ 0.4%. The control with no fertilizer application recorded the lowest number of tillers of 56.0, 98.7 and 101.8 cm at 30, 60 and 90 DAT (harvest) respectively (Table 1). The highest and lowest number of tillers per m^2 were observed with treatment containing 75% RDN+2 foliar sprays of nano urea @4% at AT and PI stages and with (control) no fertilizer application. The number of tillers were significantly affected by applying urea and its combination with foliar spray of nano urea instigated the activity of chloroplast and nitrate reductase (Changmei et al., 2002) which enhanced the growth and resulted in higher number of tillers. These findings were in accordance with the Rathnayaka et al. (2018) who stated that higher number of tillers were obtained with application of nano fertilizers in rice. This also might be due to reducing the size of the nanoparticle improved the specific surface area and number of particles in unit area of a fertilizer which would provide more opportunities for the liquid formulation for quicker penetration and nutrient uptake and thus resulting in a significant number of tillers (Lin and Zing, 2007).

However, significant variation in dry matter accumulation was noticed. The treatment supplied nitrogen through foliar application of Nano-urea @ 0.4% at Active tillering (AT) and Panicle initiation(PI) stages and 75% of RDN through urea (T_5) registered significantly higher dry matter of 158.7, 449.5 and 741.9 g m^{-2} at 30, 60 and 90 DAT (harvest), which was at par with the T_1 (recommended dose of nitrogen through urea), T_2 (50% of RDN (urea)+two foliar sprays of nano-urea @ 0.2%), T_3 (75% of RDN+two foliar sprays of nano-urea @ 0.2%) and T_4 (50% of RDN+two foliar sprays of nano-urea @ 0.4%). The lowest dry matter accumulation was obtained in absolute control (T_8) with 104.2, 270.1 and 580.9 g m^{-2} at 30, 60 and 90 DAT (harvest) respectively. Foliar application of nano-urea @ 0.4% AT and PI stages in combination with 75% of RDN significantly improved the dry matter accumulation, due to the application of the nutrients through foliar spray showed more reactivity as a result of optimum surface area which has led to efficient nutrient uptake, sunlight absorption and better photosynthesis, which resulted in more accumulation and translocation of photosynthates that eventually increased the biomass production (Mishra et al., 2020; Benzon et al., 2015).

3.2. *Effect on yield attributes*

Data revealed that the maximum number of panicles per m^2 (219), Total number of grains panicle^{-1}(218), number of filled grains panicle^{-1} (207) was recorded with the treatment which has supplied the nitrogen through foliar spray of nano urea in combination with urea i,e T_5 (75% of RDN+two foliar sprays of nano-urea @ 0.4% at AT and PI stages) which was found to be at par with treatment T_1 (Recommended dose of nitrogen (RDN) through urea) and T_3 (75% of RDN+two foliar sprays of nano-urea @ 0.2%) (Table 2). The foliar application of nano urea enhanced the absorption and translocation of nutrients in the plant which led to the increased cell division, meristematic activity and cell elongation in plants which

Table 2: Effect of nano-urea application on yield attributes, yield, and economics of rice

Treatments	Panicles m^{-2}	Grains panicle^{-1}	Filled grains panicle^{-1}	Test Weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)	B:C
T_1: Recommended dose of N through urea (100% RDN)	218	205	192	16.0	5.35	6.54	45	1.74
T_2: 50% RDN+Two foliar sprays of nano-urea @ 0.2%	206	181	166	15.8	4.66	6.09	43	1.39
T_3: 75% RDN+Two foliar sprays of nano-urea @0.2%	207	187	174	16.6	5.25	6.50	44	1.67
T_4: 50% RDN+Two foliar sprays of nano-urea @0.4%	190	183	170	15.7	5.13	6.31	45	1.54
T_5: 75% RDN+Two foliar sprays of nano-urea @0.4%	219	218	207	16.8	5.39	6.73	44	1.89
T_6: 25% RDN+Four foliar sprays of nano-urea @0.2%	199	167	151	15.8	4.39	5.31	45	1.20
T_7: 25% RDN+Four foliar sprays of nano-urea @0.4%	188	178	163	15.9	4.37	6.02	41	1.16
T_8: Control (no application of fertilizer)	158	131	112	15.4	3.50	4.50	43	1.07
SEm±	10.3	11.8	11.7	0.5	0.34	0.24	0.01	
CD (p=0.05)	31.3	35.8	35.4	NS	1.04	0.71	NS	

eventually resulted in higher number of panicles. A significant increase in number of grains per panicle might be due the increment in overall plant growth and development by virtue of more availability of nutrients as a result foliar application of nano urea leading to more assimilation and translocation of photosynthates from source to sink. These results were in accordance with the reports given by Merghany et al. (2019). Higher number of filled grains panicle^{-1} T_5 might be because initial nitrogen through soil applied urea in accumulating more biomass with better establishment of source-sink relationship foilar application of nano urea at AT and PI stages resulted in more available N in the leaf, which directly involved in photosynthate production, translocation, and assimilation chain, resulting in more no. of filled grains per panicle (Gewaily et al., 2019). Foliar application of nano urea had not showed significant influence on 1000-grain weight.

3.3. *Effect on grain, straw yield and economics*

Foliar application of nano urea significantly influenced the grain yield of rice. The data inferred from the below table (Table 2), that T_5 (75% of RDN+two foliar sprays of nano-urea @ 0.4%) (5.4 t ha^{-1}) which was on par with T_1 (Recommended dose of nitrogen (RDN) through urea recorded significantly higher grain yield T_2 (50% of RDN (urea)+two foliar sprays of nano-urea @ 0.2%) and T_3 (75% of RDN+two foliar sprays of nano-urea @ 0.2%). The significant increase in grain yield was observed with the foliar application of nano nutrients was due to the fact that increase in growth parameters like number of panicles m^{-2}, number of grains panicle^{-1}, number of filled grains panicle^{-1}, and test weight resulted in increase in grain yield and the lowest grain yield was recorded with T_8 Control (no application of fertilizer). Among the treatments, significantly higher straw yield (6.7 t ha^{-1}) was noted with the treatment T_5 (50% of RDN (urea)+two foliar sprays of nano-urea @ 0.2%) which was at par with T_1 (Recommended dose of nitrogen (RDN) through urea (6.5 t ha^{-2}), T_3 (75% of RDN+two foliar sprays of nano-urea @0.2%) (6.5 t ha^{-2}) and T_4 (50% of RDN+two foliar sprays of nano-urea @ 0.4%) (6.3 t ha^{-2}) and statistically higher when compared to that of other treatments. The lowest straw yield (4.5 t ha^{-2}) was recorded with the T_8 control (no application of fertilizer). The increase in the straw yield with the foliar application two foliar sprays of nano-urea @ 0.2% in combination with 75% RDN through urea might be due to the fact that foliar nano urea has absorbed and translocated at faster rate that resulted in higher rate of photosynthesis and more amount of dry matter accumulation which resulted in higher straw yield. These findings were in agreement with reports of Kumar et al. (2020) and Abdel-Aziz et al. (2018). Harvest index was remained non-significant in response to the foliar application of nano urea. Although the highest harvest index of (45%) was recorded with T_1 (Recommended dose of nitrogen (RDN) through urea), T_4 (50% of RDN+two foliar sprays of nano-urea @ 0.4%) and T_6 (25% of RDN+four foliar sprays of nano-urea @ 0.2%) and the lowest was recorded with T_7 (25% of RDN+four foliar sprays of nano-urea @ 0.4%) Table 2.

Among the applied treatments, T_5 (Foliar application of nano-urea @ 0.4 at AT and PI stages and 75% RDN through urea) recorded higher benefit-cost ratio of 1.89 (Table 2), and the lowest B:C ratio was recorded with the treatment T_8 control (no fertilization application). These findings are in agreement with the reports of Kumar et al. (2020).

4. Conclusion

Application of 75% of RDN+two foliar sprays of nano-urea @ 0.4% at (AT and PI) (T_5) had significantly increased the crop growth and yield of rice which resulted in the highest economic returns of rice.

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