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Response of urea and nano urea on growth and yield of transplanted rice (*Oryza sativa* L.) in hill region of Chhattisgarh

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Abstract
A field experiment was conducted to evaluate the "Response of urea and nano urea on growth and yield of transplanted rice (*Oryza sativa* L.) in hill region of Chhattisgarh" during the *Kharif* season of 2024. The study was carried out at the Raj Mohini Devi College of Agriculture and Research Station, Ambikapur, Chhattisgarh. The soil of the experimental site was alluvial in origin, characterized as slightly acidic in reaction, and primarily formed by the deposition of calcium-rich sediments over time. The experiment was laid out in Randomized Block Design with 3 replications and 8 treatments *viz.,* T_1- RDF (120:60:40 kg ha^{-1}) 3 split N application, T_2- 75% RDN (3 split N application), T_3- 50% RDN (3 split N application), T_4- 75% RDN+1 Nano Urea application at 25-30 DAT, T_5- 75% RDN+2 Nano Urea application at 25-30 DAT & 40-45 DAT, T_6- 50% RDN+1 Nano Urea application at 25-30 DAT, T_7- 50% RDN+2 Nano Urea application at 25-30 DAT & 40-45 DAT and T_8- Control. The rice variety Vikram-TCR was transplanted as test crop on 28 August 2024 and harvesting was done on 03 December 2024.
From the results, it became apparent that the treatment T_5 (75% RDN+2 Nano Urea application at 25-30 DAT & 40-45 DAT) recorded a significant mushroom in growth parameters *viz*., number of tillers, plant height, dry matter accumulation, crop growth rate and relative growth rate; and yield attributes *viz*., Number of panicles hill^{-1}, Number of grains panicle^{-1}, 1000-seed weight, Seed yield (5020 kg ha^{-1}) and Harvest index (47.13%) is also significant increase in T_5 as compared to other treatments but straw yield (5800 kg ha^{-1}) is recorded the highest in T_1- [RDF (120:60:40 kg ha^{-1}) 3 split N application] as compared to others. Furthermore, the economic analysis unveiled that the highest B: C of 2.35 also recorded in treatment T5 (75% RDN+2 Nano Urea application at 25-30 DAT & 40-45 DAT) followed by treatment T_7 (50% RDN+2 Nano Urea application at 25-30 DAT & 40-45 DAT) with B: C ratio of 2.08. Hence, it can be concluded that 2 Nano Urea application at 25-30 DAT & 40-45 DAT with 75% of RDN from urea can enhance per unit production of transplanted rice.

Keywords: Transplanted rice, yield, growth, urea, nano-urea

Introduction
Rice (*Oryza sativa* L.) belongs to family Poaceae and is believed to have originated from South-East Asia. It is one of the most important cereal crops in tropics as well as parts of temperate regions of the globe. Rice is being cultivated under diverse agro-ecologies varying from irrigated uplands and rain fed lowlands to flood- prone rice ecosystems. It is one of the most significant staple food crops consumed by more than half of the world's population (Masum *et al.*, 2013). Around the world, rice is being cultivated on an area of around 166.21 million hectares with a total production of 509.26 million metric tonnes and productivity of about 4.60 metric tons per hectare.
India, which ranks second after China, has a big rice acreage of 47.6 million hectares, providing about a quarter of Asia's total production. A record 137.82S million tons of rice were expected to be produced overall in 2023-2024. In Chhattisgarh, rice has been farmed for all recorded history, and it continues to be the state's most significant source of staple foods. The state's total rice acreage is around 3.6 million hectares with annual production of 7.9 mt.

An outrageous nutrient insufficiency in Indian agricultural soils has realized exceptional decreases in viability of yield and huge economic crisis. Although improvement in crop productivity can be accomplished by utilization of compound 3 fertilizers however, their utilization in abundance is certainly not a superior choice for long-term sustainability (Sadique *et al*., 2017) [6].

Also, conventional fertilizers in long run have negative impacts on the soil environment and the ongoing increase in the cost of mineral nitrogen fertilizers. Besides, between 40 and 70 percent of nitrogen is lost, which severely pollutes the environment (Ombodi and Saigusa 2000) [4], therefore, pushing for a need to shift to more efficient and sustainable form of nitrogenous fertilizers like controlled- release urea and nano-urea.

Nano technology represents the design, production, and application of materials at atomic, molecular, and macromolecular scales (Rehman *et al*. 2019) [5] or ability to engineer, build, process material precisely to scale of nano size ranging from 1-100 nano-meters and involves the modification or development of materials within atomic size range. It improves the material's weight, strength, speed, size, and durability, by two main approaches, in bottom-up approach the materials are manufactured from molecular components by using principle of molecular recognition and in the top-down approach nano objects are constructed from large entities without atomic level control. The two principal factors that cause the properties of nanomaterial to differ significantly from other materials are increased relative surface area and quantum effects. Nano fertilizer is a branch of nanotechnologies and is a new fertilizer produced by using nanoparticles construction, medicine microcapsule technology and chemical micro emulsion technology modifications, including nano structure fertilizer and nanoparticle-coated fertilizer, or cemented controlled release fertilizers (Zhang *et al*. 2002) [8].

Basically, Nano-urea is sub-microscopic in size, has a high surface area to volume ratio, may encapsulate nutrients and is more mobile, as a result, may improve crop productivity and plant nutrient uptake (Jakhar *et al*., 2022) [3]. Nano-urea is advantageous over traditional urea as it increases soil fertility, yield and quality parameters of the crop, is less harmful to the environment, and minimize cost and maximize profit. The primary target of nano-urea in the field of agronomy is to increase plant yield efficiency and diminish losses of nutrients (Ingale *et al*., 2013) [2].

The usage of nano-urea in rice crops would be extremely helpful in reducing any potential negative effects brought on by the widespread use of prilled-urea without sacrificing benefits to productivity and nutrition (Benzon *et al*., 2015) [1].

It was found that nano-urea could provide nutrients to crops in a regulated and timely manner, and is efficient for the germination of seeds as well as for accelerating the growth of seedlings. Similarly, several studies indicate that the exogenous application of certain nano fertilizers can significantly enhance plant development (Song *et al*., 2013) [7].

Methods and Materials

The experiment was conducted during *Kharif* season of 2024 at Instructional Farm, College of Agriculture and Research Station, Ambikapur during 2024, (Chhattisgarh). The Research Farm is located at a latitude of 23°10′N, longitude of 83°15′E and altitude of 623 mean sea level. The region comes under the northern hill (Agro-climatic Zone VII) of India. Chhattisgarh state is classified into three agro-climatic zones and Ambikapur coming into Chhattisgarh northern hill zone. The hills zone of Chhattisgarh is sub-humid, typified by a very hot summer, a relatively cold winter, and a humid and warm monsoon with moderate to high rainfall. The monsoon season normally begins in the second week of June and lasts until the last week of September. Most of the rain falls during the South-West monsoon. The average annual precipitation in the region is 1200 mm, with the rainy season lasting from the middle of June to the end of September, with occasional showers in the winter and summer months. The weekly maximum temperature in the summer can reach 43°C, while the lowest temperature can reach 4°C.

The experiment was laid-out in Randomized Block Design (RBD) with three replications. 08 treatment combinations of urea and nano urea were allocated in each replication.

Treatment no.	Treatment Details
T_1	RDF (120:60:40 kg/ha) 3 split N application
T_2	75% RDN (3 split N application)
T_3	50% RDN (3 split N application)
T_4	75% RDN+1 Nano Urea application at 25-30 DAT
T_5	75% RDN+2 Nano Urea application at 25-30 DAT & 40-45 DAT
T_6	50% RDN+1 Nano Urea application at 25-30 DAT
T_7	50% RDN +2 Nano Urea application at 25-30 DAT & 40-45 DAT
T_8	Control

Results and Discussion

Growth Attributes

According to the timetable and requirements of the investigation, the growth attributes of rice, such as plant population, No. of tillers, plant height, dry matter accumulation, crop growth rate (CGR) and relative growth rate (RGR), were made.

Plant population (m^{-2})

The data on plant population (m^{-2}) recorded at 30, 60, 90 days after transplanting (DAT), and at harvest as slightly influenced by different combinations of urea and nano urea applications. The plant population showed a slightly decline over the crop duration, which is expected due to plant competition and natural thinning. The highest plant population at all stages was observed in treatment T_5- 75% RDN +2 Nano Urea application at 25-30 DAT and 40-45 DAT, indicating a positive impact of combined application of reduced basal nitrogen with foliar nano urea.

Plant height (cm)

The data regarding the mean plant height (cm) of transplanted rice as influenced by different levels of urea and nano urea application at various crop growth stages. The results revealed that plant height increased progressively with crop age and was found to be the highest at harvest. A relatively slow growth rate was observed during the early vegetative stage up to 30 DAT, which accelerated significantly during the 30 to 90 DAT period, and then slightly slowed until maturity. The mean plant heights recorded at 30, 60, 90 DAT and at harvest were 35.1, 68.5, 91.2, and 97.4 cm, respectively.

Number of tillers plant^{-1}

The data pertaining to the mean number of tillers plant^{-1} as influenced by the application of urea and nano urea through different treatments at successive crop growth stages. The numerical values revealed that the number of tillers plant^{-1} increased progressively from 30 DAT to 90 DAT, followed by a slight reduction at harvest. The average number of tillers plant^{-1} recorded across all treatments at 30, 60, 90 DAT and at harvest were 5.36, 10.03, 12.44 and 11.75, respectively. The effect of different treatments on the number of tillers plant^{-1} was found to be statistically significant at all growth stages. At 30 DAT, the treatment T_5- 75% RDN +2 Nano Urea application at 25-30 DAT and 40-45 DAT recorded the highest number of tillers (6.3), which was statistically superior to the rest of the treatments. At 60 DAT and 90 DAT, T_5 continued to show the maximum number of tillers (11.1 and 13.9 respectively), indicating the synergistic effect of reduced nitrogen dose complemented with nano urea foliar application. At harvest too, treatment T_5 recorded the highest tiller count (13.2), reflecting sustained tillering under this nutrient regime.

Dry matter accumulation (g plant^{-1})

The data regarding mean dry matter accumulation (g plant^{-1}) of rice as affected by foliar application of nano-urea and conventional urea under various treatments. With the advancing age of the crop, dry matter accumulation (g plant^{-1}) increased progressively. Up to 30 DAT, the rate of dry matter accumulation was relatively low. Between 30 to 60 DAT, the accumulation rate increased rapidly, followed by a steady gain up to harvest. The mean dry matter accumulation recorded at 30 DAT, 60 DAT, 90 DAT, and at harvest across all treatments were 4.73, 15.1, 29.6, and 38.1 g plant^{-1}, respectively.

Crop Growth Rate (g plant^{-1} day^{-1})

The data regarding the crop growth rate (CGR) of transplanted rice (*Oryza sativa* L.) as influenced by urea and nano urea application at different crop stages. The CGR was assessed during the intervals of 30–60 DAT, 60–90 DAT, and 90 DAT–at harvest. The results indicated that crop growth rate was significantly influenced by the foliar application of nano urea. The highest CGR during all intervals was recorded in treatment T_5- 75% RDN +2 Nano Urea application at 25-30 DAT and 40-45 DAT, which registered 0.41, 0.54, and 0.32 g plant^{-1} day^{-1}, respectively.

Relative Growth Rate (g g^{-1} day^{-1})

The relative growth rate (RGR) of transplanted rice, expressing dry matter accumulation per unit of existing biomass, was evaluated at 30–60 DAT, 60–90 DAT, and 90 DAT–at harvest intervals. The results revealed that RGR was significantly influenced by the application of nano urea. The highest relative growth rate was recorded in T_5- 75% RDN +2 Nano Urea application at 25-30 DAT and 40-45 DAT, registering 0.033, 0.022, and 0.012 g g^{-1} day^{-1}during 30–60 DAT, 60–90 DAT, and 90 DAT–harvest, respectively. The lowest RGR was recorded in T_8 – Control, with values of 0.025, 0.016, and 0.008 g g^{-1} day^{-1}, respectively, across the same growth intervals.

Yield Attributes

Yield attributing characters such as number of panicles plant^{-1}, grains panicle^{-1}, test weight or 1000 grain weight (g), straw yield (kg ha^{-1}), Seed yield (kg ha^{-1}) and harvest index (%).

Number of Panicles hill^{-1}

Data regarding the number of panicles hill^{-1} at harvest as influenced by urea and nano urea application. Among all the treatments, the maximum number of panicles per plant (10.9) was recorded under T_5 (75% RDN +2 Nano Urea application at 25-30 DAT and 40-45 DAT), which was statistically superior over all other treatments. This was followed by T_4 (75% RDN +1 Nano Urea application at 25-30 DAT (10.2) and T_1- RDF (120:60:40 kg ha^{-1}) 3 split N application (10.5). The lowest number of panicles per plant (8.2) was observed in T_8 (Control).

Number of Grains Panicle^{-1}

The data on the number of grains panicle^{-1}, including total, filled, and unfilled grains, were recorded at harvest. The highest total number of grains panicle^{-1} (99.8) was observed under T_5- 75% RDN +2 Nano Urea application at 25-30 DAT and 40-45 DAT, which was significantly superior over other treatments. This treatment also recorded the highest number of filled grains (93.4) and comparatively lower unfilled grains (6.4). Conversely, the lowest total grains (73.5), filled grains (61.2), and the highest unfilled grains (12.3) were observed in T_8 (Control).

Test Weight (1000 Grain Weight)

The maximum test weight (25.4 g) was recorded in T_5 (75% RDN +2 Nano Urea application at 25-30 DAT and 40-45 DAT), followed closely by T_1-RDF (120:60:40 kg/ha) 3 split N application (25.1 g) and T_4 – 75% RDN +1 Nano Urea application at 25-30 DAT (24.9 g). The lowest test weight (22.8 g) was observed in T_8 (Control). The higher test weight under nano urea treatments might be attributed to better grain filling due to improved nitrogen availability, enhanced photosynthetic activity, and hormonal regulation during the grain development phase. The findings suggest the critical role of nano urea in boosting grain quality and density.

Seed yield (kg ha^{-1})

Among the treatments, the highest seed yield (5020 kg ha^{-1}) was recorded in T_5 (75% RDN +2 Nano urea application at 25-30 DAT and 40-45 DAT). This treatment was statistically superior over all other treatments and was followed by T_1 (RDF with 3 split N application) and T_7 (50% RDN +2 Nano Urea application at 25-30 DAT & 40-45 DAT), which recorded seed yields of 4960 kg ha^{-1} and 4560 kg ha^{-1} respectively. The lowest seed yield (3290 kg ha^{-1}) was observed in T_8 (Control). The increase in seed yield with nano urea application can be attributed to enhanced nutrient uptake, better assimilation, and improved physiological functions such as photosynthesis and grain filling.

Straw yield (kg ha^{-1})

The maximum straw yield (5800 kg ha^{-1}) was recorded under T_1 (RDF with 3 split N application), which was statistically at par with T_5 (75% RDN +2 Nano Urea application at 25-30 DAT and 40-45 DAT) recording 5630 kg ha^{-1}. These treatments were followed by T_4 and T_7, which recorded straw yields of 5540 and 5280 kg ha^{-1} respectively. The minimum straw yield (4150 kg ha^{-1}) was obtained in T8 (Control). The increase in straw yield in nano urea applied plots may be due to improved vegetative growth, leaf area development, and photosynthetic efficiency, ultimately contributing to better biomass production.

Harvest Index (%)

The highest harvest index (47.13%) was recorded in T_5 (75% RDN +2 Nano Urea application at 25-30 DAT and 40-45 DAT), followed closely by T_4 (46.10%) and T_1 (46.08%), indicating improved partitioning of assimilates towards economic yield (grain) in these treatments.

The lowest harvest index (44.22%) was noted in T_8 (Control). These results indicate that the integration of nano urea with reduced chemical N fertilization enhances nitrogen use efficiency and promotes better grain-to-straw ratio.

Economics
The most crucial aspect of any agronomic intervention is its economic feasibility. Farmers are likely to adopt a new input package only if it ensures profitable returns. Hence, an economic evaluation was undertaken for different treatments. The data regarding cost of cultivation (₹ha^{-1}), gross return (₹ha^{-1}), net return (₹ha^{-1}), and B:C ratio.

Cost of cultivation (₹ha^{-1})
The total cost of cultivation includes expenses from field preparation to harvesting. Among all treatments, the highest cost of cultivation was recorded under T_1 61120 (₹ha^{-1}), while the lowest cost was observed in the control (T_8) with 47455 (₹ha^{-1}). Cost variations were mainly due to differential fertilizer use and nano urea application schedules. The treatments involving nano urea had relatively lower costs than the recommended dose of fertilizers.

Gross return (₹ha^{-1})
Gross returns were calculated based on grain and straw yields using government-fixed market prices. The maximum gross return (₹164065 ha^{-1}) was recorded in T_5 (75% RDN +2 Nano Urea application at 25-30 DAT and 40-45 DAT), followed by T_1 (₹161700 ha^{-1}) and T_7 (₹14928 ha^{-1}). The lowest gross return (₹108215 ha^{-1}) was reported in the control treatment (T_8), indicating poor yield performance without fertilizer or nano urea. This trend highlights the beneficial role of nano urea in increasing crop productivity.

Net return (₹ha^{-1})
The net return, representing profit after deducting the cost of cultivation, was highest in T_5 (₹115045 ha^{-1}) followed by T_7 (₹100715 ha^{-1}) and T_1 (₹100580 ha^{-1}). This shows that T_5, despite a moderate cultivation cost, resulted in maximum profitability due to significantly higher yield. In contrast, T_8 and T_3 recorded the lowest net returns of ₹60760 $ha^{-1}$and ₹86515 ha^{-1}, respectively.

Benefit-Cost Ratio
The Benefit-Cost ratio is an important indicator of profitability. It ranged from 1.28 (T_8) to 2.35 (T_5). Treatments with nano urea foliar application (T_4, T_5, T_6 and T_7) consistently outperformed both the full RDF and reduced urea treatments. Particularly, T_5 (75% RDN +2 Nano Urea application at 25-30 DAT and 40-45 DAT) not only provided the highest B:C ratio (2.35) but also demonstrated the potential to achieve higher economic returns with reduced nitrogen input. This suggests that integrating nano urea can enhance nutrient use efficiency and profitability.
Highest B:C (2.35) recorded in T_5, followed by T_7 (2.08) and T_4 (2.05), outperforming T_1 (1.65) and T_8 (1.28). Nano-urea improved efficiency.

Table 1: Effect of urea and nano urea application on plant height (cm)

Treatments	Plant height (cm)			
	30 DAT	60 DAT	90 DAT	at harvest
T_1- RDF (120:60:40 kg ha^{-1}) 3 split N application	38.20	72.41	96.70	100.50
T_2- 75% RDN (3 split N application)	35.91	69.80	93.20	97.60
T_3- 50% RDN (3 split N application)	32.40	65.10	87.60	91.31
T_4- 75% RDN+1 Nano Urea application at 25-30 DAT	37.10	71.21	95.11	99.10
T_5- 75% RDN+2 Nano Urea application at 25-30 DAT & 40-45 DAT	38.01	73.50	97.31	101.20
T_6- 50% RDN+1 Nano Urea application at 25-30 DAT	34.10	67.20	89.50	93.41
T_7- 50% RDN+2 Nano Urea application at 25-30 DAT & 40-45 DAT	35.50	69.40	91.80	95.71
T_8- Control	29.60	58.21	78.70	81.50
SEm±	0.82	1.11	1.34	1.25
CD (P=0.05)	2.45	3.32	4.01	3.72

Table 2: Effect of urea and nano urea application on Number of panicle $plant^{-1}$, Number of grain $panicle^{-1}$ and 1000 Grain weight (g)

Treatments	Number of panicles $hill^{-1}$	Number of grain $panicle^{-1}$			1000 Grain weight (g)
		Total grains $panicle^{-1}$	Filled grains $panicle^{-1}$	Unfilled grain $panicle^{-1}$	
T_1- RDF (120:60:40 kg ha^{-1}) 3 split N application	10.5	96.3	90.1	6.2	25.1
T_2- 75% RDN (3 split N application)	9.7	91.5	83.6	7.9	24.4
T_3- 50% RDN (3 split N application)	8.9	85.3	75.4	9.9	23.5
T_4- 75% RDN+1 Nano Urea application at 25-30 DAT	10.2	94.7	88.5	6.2	24.9
T_5- 75% RDN+2 Nano Urea application at 25-30 DAT & 40-45 DAT	10.9	99.8	93.4	6.4	25.4
T_6- 50% RDN+1 Nano Urea application at 25-30 DAT	9.4	89.6	80.2	9.4	24.0
T_7- 50% RDN+2 Nano Urea application at 25-30 DAT & 40-45 DAT	9.8	92.4	83.3	9.1	24.6
T_8- Control	8.2	73.5	61.2	12.3	22.8
S.Em±	0.15	1.46	1.28	0.44	0.18
CD (P=0.05)	0.45	1.25	3.76	1.31	0.54

Table 3: Cost economics

Treatments	Cost of cultivation (₹ ha^{-1})	Gross return (₹ ha^{-1})	Net return (₹ ha-1)	B:C Ratio
T_1- RDF (120:60:40 kg ha^{-1}) 3 split N application	61120	161700	100580	1.65
T_2- 75% RDN (3 split N application)	48820	141410	92590	1.89
T_3- 50% RDN (3 split N application)	48365	134880	86515	1.79
T_4- 75% RDN+1 Nano Urea application at 25-30 DAT	48920	149050	100130	2.05
T_5- 75% RDN+2 Nano Urea application at 25-30 DAT & 40-45 DAT	49020	164065	115045	2.35
T_6- 50% RDN+1 Nano Urea application at 25-30 DAT	49020	141645	92625	1.89
T_7- 50% RDN+2 Nano Urea application at 25-30 DAT & 40-45 DAT	48565	149280	100715	2.08
T_8- Control	47455	108215	60760	1.28

Conclusion

Combining nano urea with reduced basal nitrogen (75% RDN) in T_5- 75% RDN+2 Nano Urea application at 25-30 DAT and 40-45 DAT significantly improved growth parameters (plant population, tillers, plant height, dry matter accumulation, CGR, and RGR) and yield parameters (panicles, grains per panicle, test weight, seed yield, straw yield, and harvest index) compared to the control and other treatments. T_5 performed comparably or better than T_1 (100% RDF), suggesting that nano urea can reduce dependency on conventional urea without compromising performance.

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