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Effect of Nano Urea on Yield Attributes Characteristics in Transplanted Rice (*Oryza sativa* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Original Research Article

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ABSTRACT

A field experiment was conducted at the Students Instructional Farm, Department of Agronomy, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur (U.P.) during the two consecutive *kharif* seasons of 2023 and 2024 to evaluate. The experiment was laid-out in a

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Randomized Block Design with 3 replications and 9 treatments. *i.e*. T_1: 125% RDN through Urea (50% as basal + 25% at active tillering stage and panicle initiation), T_2: T_1+ Two spray of Nano Urea at active tillering stage and panicle initiation, T_3: 100% RDN through Urea in three splits (50% as basal + 25% at active tillering stage and panicle initiation stage), T_4: T_3 + Two spray of nano urea at active tillering stage and panicle initiation stage (@ 4 ml/ litre of water, T_5: 75% RDN through urea (50% as basal + 25% active tillering stage and panicle initiation stage), T_6: T_5 + Two spray on nano urea at active tillering stage and panicle initiation stage, T_7: 50% RDN through urea (50% basal + 25% at active tillering stage and panicle initiation stage), T_8: T_7+ Two spray of nano urea at active tillering stage and panicle initiation stage, T_9: Control. Rice variety *Sarju-52* was sown. Recorded yield attributes and yield parameters showed that maximum number of panicles (m^{-2}), total number of tillers (m^{-2}), length of panicle (cm), number of productive tillers (m^{-2}), test weight (1000 grains) (g.), total number of grains panicles^{-1}, number of filled grains panicles^{-1}, grain yield (q ha^{-1}), straw yield (q ha^{-1}), biological yield (q ha^{-1}), harvest index (%) were achieved under treatment T_2: T_1+ Two spray of nano urea at active tillering stage and panicle initiation.

Keywords: RDN; RDF; nano urea; rice.

1. INTRODUCTION

Rice (Oryza sativa) is a crucial cereal crop in India, belonging to the Poaceae family and Oryza genus. It is a self-pollinated, short-day, C3 plant with a fibrous root system. The plant features leave with a sheath and blade, and a branched panicle bearing spikelet's. The fruit is a caryopsis. Rice is grown worldwide across diverse agro-climatic zones and is India's most important staple food. It contains 6-7% protein, 2-2.5% fat, and low calcium. Producing 1 kg of rice grain typically requires about 5,000 litres of water. Rice serves as the primary food source for more than half the global population, with demand set to rise alongside population growth Singh & Verma. (2018).

"Nano fertilizers supply essential nutrients to crops gradually according to their growth needs, as they contain nutrients and growth-enhancing substances enclosed within nanoscale polymer coatings" (Rai et al., 2012). "These nano scale polymers ensure low and target efficient release for providing the nutrients to the crop and thus increase nutrient use efficiency. Nano fertilizers also play an important role in soil health by building up soil organic carbon, improving soil aggregation and water holding capacity" (Rai *et al*., 2012). "Nano fertilizers being encapsulated in nano particles increase the uptake of nutrients" (Tarafdar *et al.,* 2014). "These fertilizers were manufactured through biological process are eco-friendly and have been designed to match inorganic fertilizers in terms of nutrient composition and application rates. Nano fertilizers are synthesized to regulate the release of nutrients more efficiently than ordinary fertilizers" (Liu & Lal, 2015). Thus, the application of nano fertilizers seems promising that may ensure efficient translocation of nutrients to the desired parts of plants as required.

"Nanotechnology plays a vital role in crop production with environmental safety, ecological sustainability, and economic stability" (Kumar *et al.,* 2020). "Enhancement of various physiological parameters such as photosynthetic activity and nitrogen metabolism using nano nitrogen has been reported in rice, soybean, and groundnut" (Benzon *et al.,* 2015). (Saharan *et al.,* 2016) reported that "foliar treatment with nano urea in chickpea and maize enhanced the growth of seedlings and biomass". Sheoran *et al.*, 2021 reported that "application of nano urea in wheat crop resulted in increase in morphological and yield parameters efficiently". "Nano urea application at active tillering stage is predicted to enhance the input efficiency and boost rice yield" (Velmurugan *et al.,* 2021). "The yield obtained with 50% less nitrogen as compared to the N applied under farmers fertilizer practice (FFP) and application of nano urea with two foliar sprays gave higher yield in standing winter season crops like wheat, lentil, field pea and mustard" (Yogendra Kumar *et al.,* 2020).

"Urea is a standard nitrogen source in fertilizer, but when it meets water, it hastily breaks down into ammonia which leads to the problem of leaching. Farmers must apply additional fertilizer to crops to cover that loss, which puts a strain on the economy, especially in developing regions of the globe where food supplies are unstable and populations are increasing. By releasing small

accounts of nitrogen when the crop needs it, slow-release nitrogen fertilizers address the current issues of nitrogen loss and increase the ability of nitrogen to maximize the yield" (Shivay *et al.,* 2000). "Neem coated urea (NCU) is an indigenous nitrification inhibitor that is reported to enhance rice yield, growth, and uptake of nitrogen fertilizer. It is also reported to extend the lifespan and maximize the effectiveness of nitrogen fertilizers on rice. Nitrification inhibiting properties of neem and its role in increasing nutrient use efficiency (NUE) in rice was first reported by" (Bains *et al.,* 1971).

2. MATERIALS AND METHODS

Experimental site: A field experiment was conducted during two consecutive *Kharif* season of 2023 and 2024 at Student's Instructional Farm of Chandra Shekhar Azad University of Agriculture and Technology, Kanpur. The Kanpur Nagar is a city in central Uttar Pradesh situated at 125.9 meters above sea level on the alluvial tract of the Gangetic plains. It is coordinated at 25° - 28° North latitude and 79°- 80° East longitude. This northern zone is characterized by the semi-arid climate and rich alluvial soil s. About 935 mm of rainfalls is received each year on average. The soil of experiment plot was sandy loam in texture having 0.45% organic carbon, 189.12 kg ha^{-1} available N, 14.60 kg ha^{-1} available P, 167.31 kg ha^{-1} K, 18.5 kg ha^{-1} in both the years. To assess the most suitable rice variety the "Effect of nano urea on growth, productivity, and economic return in transplanted rice (*Oryza sativa* L.). using rice variety Sarju 52.

Treatment details: The study was conducted using a Randomized Block Design with three replications and nine different treatments. The treatments included: T_1, application of 125% RDN through urea (50% as basal and 25% each during active tillering and panicle initiation); T_2, T_1 along with two sprays of nano urea at active tillering and panicle initiation stages; T_3, 100% RDN through urea applied in three splits (50% basal, 25% at active tillering, and 25% at panicle initiation); T_4, T_3 supplemented with two nano urea sprays at 4 ml per litre of water during the same stages; T_5, 75% RDN through urea with similar split applications; T_6, T_5 with two nano urea sprays at the same stages; T_7, 50% RDN through urea applied in the same split manner; T_8, T_7 with two nano urea sprays at active tillering and panicle initiation; and T_9, the untreated control.

3. RESULTS AND DISCUSSION

3.1 Number of Panicle (m^{-2})

The data presenting on number of panicle (m^{-2}) is presented in Table 1. The results demonstrated that different nano fertilizers significantly influenced number of panicles (m^{-2}) during the years 2023, 2024, and pooled basis. The number of panicles (m^{-2}) was recorded significantly maximum during the year 2023, 2024 and pooled basis with application of treatment T_2 which included (T_1+ Two spray of nano urea at active tillering stage and panicle initiation) (490.61, 532.04 and 511.33) respectively years. Followed by treatment T_1 (125% RDN through Urea (50% as basal + 25% at active tillering stage and Panicle initiation), T_4 (T_3 + Two spray of Nano Urea at active tillering stage and panicle initiation stage (@ 4 ml/ litre of water), T_3 (100% RDN through Urea in three splits (50% as basal + 25% at active tillering stage and Panicle initiation stage), T_6 **(**T_5 + Two spray on Nano Urea at active tillering stage and panicle initiation stage) and T_5 (75% RDN through Urea 50% as basal + 25% active tillering stage and panicle initiation stage). And lowest number of panicles (m^{-2}) ware recorded under the treatment T_9 (Control) (196.66, 209.35 and 203.00) respectively years. Also reported the similar results Jassim *et al*., (2019).

3.2 Total Number of Tillers (m^{-2})

The data pertaining on total number of tillers (m^{-2}) is presented in Table 1. The results demonstrated that different nano fertilizers significantly influenced total number of tillers (m^{-2}) during the years 2023, 2024, and pooled basis. The total number of tillers (m^{-2}) was recorded significantly maximum during the year 2023, 2024 and pooled basis with application of treatment T_2 which included (T_1+ Two spray of nano urea at active tillering stage and Panicle initiation) (499.83, 540.74 and 520.28) respectively years. Followed by treatment T_1 (125% RDN through Urea (50% as basal + 25% at active tillering stage and Panicle initiation), T_4 (T_3 + Two spray of Nano Urea at active tillering stage and panicle initiation stage (@ 4 ml/ litre of water), T_3 (100% RDN through Urea in three splits (50% as basal + 25% at active tillering stage and Panicle initiation stage), T_6 **(**T_5 + Two spray on Nano Urea at active tillering stage and panicle initiation stage) and T_5 (75% RDN through Urea 50% as basal + 25% active tillering stage and panicle initiation stage). And lowest

total number of tillers (m^{-2}) ware recorded under the treatment T_9 (Control) (215.86, 227.95 and 221.91) respectively years. Also reported the similar results Dhamanker *et al.,* (2023), Rawate *et al.,* (2022) Their studies demonstrated that nano fertilizers, due to their slow release and targeted nutrient delivery, enhance nutrient use efficiency and overall crop performance compared to conventional fertilizers.

3.3 Length of Panicle (cm)

The data pertaining on length of panicle (cm) is presented in Table 1. The results demonstrated that different nano fertilizers significantly influenced length of panicle (cm) during the years 2023, 2024, and pooled basis. The length of panicle (cm) was recorded significantly maximum during the year 2023, 2024 and pooled basis with application of treatment T_2 which included (T_1+ Two spray of nano urea at active tillering stage and Panicle initiation) (26.06, 26.13 and 26.09 cm) respectively years. Which were being statistically at par treatment T_1 (125% RDN through Urea (50% as basal + 25% at active tillering stage and Panicle initiation). And lowest length of panicle (cm) ware recorded under the treatment T_9 (Control) (17.80, 17.97 and 17.88 cm) respectively years.

3.4 Number of Productive Tillers (m^{-2})

The data pertaining on number of productive tillers (m^{-2}) is presented in Table 2. The results demonstrated that different nano fertilizers significantly influenced number of productive tillers (m^{-2}) during the years 2023, 2024, and pooled basis.

The number of productive tillers (m^{-2}) was recorded significantly maximum during the year 2023, 2024 and pooled basis with application of treatment T_2 which included (T_1+ Two spray of nano urea at active tillering stage and Panicle initiation) (470.86, 513.84 and 492.35) respectively years. Which were being statistically at par treatment T_1 (125% RDN through Urea (50% as basal + 25% at active tillering stage and Panicle initiation). And lowest number of productive tillers (m^{-2}) ware recorded under the treatment T_9 (Control) (162.45, 179.47 and 170.96) respectively years. Also reported the similar results Rahman *et al.,* (2014) Rose *et al*., (2015).

3.5 Number of Unproductive Tillers (m^{-2})

The data pertaining on number of unproductive tillers (m^{-2}) is presented in Table 2. The results demonstrated that different nano fertilizers significantly influenced number of unproductive tillers (m^{-2}) during the years 2023, 2024, and pooled basis.

The number of unproductive tillers (m^{-2}) was recorded significantly maximum during the year 2023, 2024 and pooled basis under the treatment T_9 (Control) (34.21, 29.87 and 32.04) respectively years. Followed by T_7, T_8, T_5, T_6, T_3, T_4 and T_1. And lowest number of unproductive tillers (m^{-2}) ware recorded under the treatment T_2 which included (T_1+ Two spray of nano urea at active tillering stage and Panicle initiation) (19.75, 18.20 and 18.97) respectively years. Also reported the similar results Rahman *et al.,* (2014) Rose *et al*., (2015).

3.6 Test Weight (1000 grains) (g.)

The data pertaining on test weight is presented in Table 2. The results demonstrated that different nano fertilizers non-significantly influenced test weight during the years 2023, 2024, and pooled basis.

The test weight was recorded maximum during the year 2023, 2024 and pooled basis with application of treatment T_2 which included (T_1+ Two spray of nano urea at active tillering stage and Panicle initiation) (22.48, 22.54 and 22.51 g.) respectively years. Followed by treatment T_1, T_4, T_3, T_6. And lowest test weight ware recorded under the treatment T_9 (Control) (21.08, 21.14 and 21.11 g.) respectively years. Also reported the similar results Arya *et al*., (2022), Karanjikar *et al*., (2021).

3.7 Total Number of Grains Panicles^{-1}

The data pertaining on total number of grains panicles^{-1} is presented in Table 3. The results demonstrated that different nano fertilizers significantly influenced total number of grains panicles^{-1} during the years 2023, 2024, and pooled basis.

Total number of grains panicles^{-1} was recorded significantly maximum during the year 2023, 2024 and pooled basis with application of treatment T_2 which included (T_1+ Two spray of nano urea at active tillering stage and Panicle initiation) (269.00, 274.70 and 271.85) respectively years. Which were being statistically at par treatment T_1 (125% RDN through Urea (50% as basal + 25% at active tillering stage and Panicle initiation). And treatment T_4, T_3, T_6, T_5 higher over rest of treatments. And lowest total number of grains panicles^{-1} ware recorded under

Table 1. Effect of nano urea as influence by yield attributes characteristic in panicles of transplanted rice

Treatments	Number of panicles m^{-2}			Number of total tillers m^{-2}			Length of panicle (cm)		
	2023	2024	Pooled	2023	2024	Pooled	2023	2024	Pooled
T_1: 125% RDN through Urea (50% as basal + 25% at active tillering stage and Panicle initiation).	467.58	489.88	478.73	477.04	499.00	488.02	25.67	25.92	25.80
T_2: T_1+ Two spray of Nano Urea at active tillering stage and Panicle initiation.	490.61	532.04	511.33	499.83	540.74	520.28	26.06	26.13	26.09
T_3: 100% RDN through Urea in three splits (50% as basal + 25% at active tillering stage and Panicle initiation stage).	414.00	429.87	421.94	425.82	440.92	433.37	24.37	24.86	24.61
T_4: T_3 + Two spray of Nano Urea at active tillering stage and panicle initiation stage (@ 4 ml/ litre of water.	423.73	469.30	446.52	435.07	479.19	457.13	25.00	25.56	25.28
T_5: 75% RDN through Urea (50% as basal + 25% active tillering stage and panicle initiation stage)	375.31	374.12	374.72	390.52	388.23	389.37	22.12	22.80	22.46
T_6: T_5 + Two spray on Nano Urea at active tillering stage and panicle initiation stage	407.03	414.56	410.80	421.51	427.58	424.55	22.94	23.17	23.05
T_7: 50% RDN through Urea (50% basal + 25% at active tillering stage and panicle initiation stage)	310.58	334.11	322.34	327.83	350.66	339.24	21.29	21.65	21.47
T_8: T_7+ Two spray of Nano Urea at active tillering stage and panicle initiation stage	340.38	359.17	349.77	356.04	373.73	364.89	21.75	22.16	21.95
T_9: Control	196.66	209.35	203.00	215.86	227.95	221.91	17.80	17.97	17.88
SE(d)±	9.27	9.44	8.57	7.95	7.13	6.63	0.68	0.69	0.61
CD (*p*=0.05)	19.65	20.01	18.18	16.86	15.12	14.06	1.44	1.47	1.29

Table 2. Effect of nano urea as influence by yield attributes characteristic in tillers of transplanted rice

Treatments	Number of productive tillers m^{-2}			Number of unproductive tillers m^{-2}			Test weight (1000 grains) g.		
	2023	2024	Pooled	2023	2024	Pooled	2023	2024	Pooled
T_1: 125% RDN through Urea (50% as basal + 25% at active tillering stage and Panicle initiation).	447.32	471.39	459.35	20.26	18.49	19.37	22.41	22.47	22.44
T_2: T_1+ Two spray of Nano Urea at active tillering stage and Panicle initiation.	470.86	513.84	492.35	19.75	18.20	18.97	22.48	22.54	22.51
T_3: 100% RDN through Urea in three splits (50% as basal + 25% at active tillering stage and Panicle initiation stage).	392.52	410.75	401.63	21.48	19.12	20.30	22.29	22.34	22.32
T_4: T_3 + Two spray of Nano Urea at active tillering stage and panicle initiation stage (@ 4 ml/ litre of water.	403.09	450.24	426.67	20.64	19.06	19.85	22.36	22.40	22.38
T_5: 75% RDN through Urea (50% as basal + 25% active tillering stage and panicle initiation stage)	348.41	350.49	349.45	26.90	23.64	24.93	22.15	22.23	22.19
T_6: T_5 + Two spray on Nano Urea at active tillering stage and panicle initiation stage	380.27	392.31	386.29	26.76	22.25	24.50	22.23	22.28	22.26

Treatments	Number of productive tillers m^{-2}			Number of unproductive tillers m^{-2}			Test weight (1000 grains) g.		
	2023	2024	Pooled	2023	2024	Pooled	2023	2024	Pooled
T_7: 50% RDN through Urea (50% basal + 25% at active tillering stage and panicle initiation stage)	281.18	308.06	294.62	29.40	26.05	27.72	22.00	22.07	22.04
T_8: T_7+ Two spray of Nano Urea at active tillering stage and panicle initiation stage	312.08	333.83	322.96	28.30	25.34	26.81	22.09	22.15	22.12
T_9: Control	162.45	179.47	170.96	34.21	29.87	32.04	21.08	21.14	21.11
SE(d)±	6.85	7.10	7.43	2.04	1.94	2.01	0.45	0.43	0.47
CD (*p*=0.05)	14.52	15.05	15.76	4.32	4.10	4.26	NS	NS	NS

Table 3. Effect of nano urea as influence by yield attributes characteristic in grains of panicle in transplanted rice

Treatment	Total number of grains $panicle^{-1}$			Number of filled grains $panicle^{-1}$			Number of unfilled grains $panicle^{-1}$		
	2023	2024	Pooled	2023	2024	Pooled	2023	2024	Pooled
T_1: 125% RDN through Urea (50% as basal + 25% at active tillering stage and Panicle initiation).	259.70	264.12	261.91	243.08	250.04	246.56	16.62	14.08	15.34
T_2: T_1+ Two spray of Nano Urea at active tillering stage and Panicle initiation.	269.00	274.70	271.85	255.55	262.58	259.06	13.45	12.12	12.78
T_3: 100% RDN through Urea in three splits (50% as basal + 25% at active tillering stage and Panicle initiation stage).	222.40	238.19	230.29	203.30	221.10	212.20	19.10	17.09	18.09
T_4: T_3 + Two spray of Nano Urea at active tillering stage and panicle initiation stage (@ 4 ml/ litre of water.	240.60	254.80	247.70	221.88	239.36	230.62	18.72	15.44	17.07
T_5: 75% RDN through Urea (50% as basal + 25% active tillering stage and panicle initiation stage)	182.50	203.70	193.10	157.22	180.72	168.97	25.28	22.98	24.12
T_6: T_5 + Two spray on Nano Urea at active tillering stage and panicle initiation stage	201.90	214.06	207.97	177.86	192.56	185.21	24.04	21.50	22.77
T_7: 50% RDN through Urea (50% basal + 25% at active tillering stage and panicle initiation stage)	132.80	151.70	142.25	106.68	126.92	116.80	26.12	24.78	25.45
T_8: T_7+ Two spray of Nano Urea at active tillering stage and panicle initiation stage	155.20	172.08	163.64	129.26	148.22	138.74	25.94	23.86	24.90
T_9: Control	96.70	97.40	97.05	65.68	67.36	66.52	31.02	30.04	30.53
SE(d)±	5.43	5.56	5.15	3.37	3.54	3.54	1.45	1.50	1.49
CD (*p*=0.05)	11.51	11.79	10.91	7.14	7.50	7.51	3.08	3.17	3.16

the treatment T_9 (Control) (96.70, 97.40 and 97.05) respectively years. Also reported the similar results Khandey *et al.,* (2017). Their study found that the use of nano-synergids and nano-fertilizers improved rice germination speed, early growth, antioxidant enzyme activities, and overall crop performance.

3.8 Number of Filled Grains Panicles^{-1}

The data pertaining on number of filled grains panicles^{-1} is presented in Table 3. The results demonstrated that different nano fertilizers significantly influenced number of filled grains panicles^{-1} during the years 2023, 2024, and pooled basis.

Number of filled grains panicles^{-1} was recorded significantly maximum during the year 2023, 2024 and pooled basis with application of treatment T_2 which included (T_1+ Two spray of nano urea at active tillering stage and Panicle initiation) (255.55, 262.58 and 259.06) respectively years. followed by treatment T_1, T_4, T_3, T_6, T_5. And lowest number of filled grains panicles^{-1} ware recorded under the treatment T_9 (Control) (65.68, 67.36 and 66.52) respectively years. Also reported the similar results Lemraski *et al.,* (2017), Midde *et al.,* (2021) studied the effect of nano nitrogen fertilizers on rice growth, yield, and nutrient use efficiency. Their research showed that foliar application of nano urea at critical growth stages such as active tillering and panicle initiation significantly increased plant height, tiller number, grain yield, and straw yield.

3.9 Number of Unfilled Grains Panicle^{-1}

The data pertaining on number of unfilled grains panicles^{-1} is presented in Table 3. The results demonstrated that different nano fertilizers significantly influenced number of unfilled grains panicles^{-1} during the years 2023, 2024, and pooled basis.

Number of unfilled grains panicles^{-1} was recorded significantly maximum during the year 2023, 2024 and pooled basis with application of treatment T_9 (Control) (31.02, 30.04 and 30.53) respectively years. followed by treatment T_7, T_8, T_5, T_6, T_3, T_4. And lowest number of unfilled grains panicles^{-1} ware recorded under the treatment T_2 which included (T_1+ Two spray of nano urea at active tillering stage and Panicle initiation) (13.45, 12.12 and 12.78) respectively years. Also reported the similar results Lemraski *et al.,* (2017) studied the effects of nano chelated iron fertilizer on rice agronomic traits and yield. Their research demonstrated that foliar application of nano chelated iron fertilizer increased biological yield by 27%, reduced the number of hollow grains by 25%, and enhanced protein content by 13%. Additionally, this nano fertilizer improved the concentration of essential nutrients such as nitrogen, phosphorus, potassium, iron, and zinc in rice grains.

3.10 Grain Yield (q ha^{-1})

The data pertaining on grain yield (q ha^{-1}) is presented in Table 4. The results demonstrated that different nano fertilizers significantly influenced grain yield (q ha^{-1}) during the years 2023, 2024, and pooled basis.

The grain yield (q ha^{-1}) was recorded significantly maximum during the year 2023, 2024 and pooled basis with application of treatment T_2 which included (T_1+ Two spray of nano urea at active tillering stage and Panicle initiation) (47.94, 49.66 and 48.79 q ha^{-1}) respectively years. Which ware being at par treatment T_1 (125% RDN through Urea (50% as basal + 25% at active tillering stage and Panicle initiation), T_4 (T_3 + Two spray of Nano Urea at active tillering stage and panicle initiation stage (@ 4 ml/ litre of water), T_3 (100% RDN through Urea in three splits (50% as basal + 25% at active tillering stage and Panicle initiation stage), T_6 **(**T_5 + Two spray on Nano Urea at active tillering stage and panicle initiation stage) and T_5 (75% RDN through Urea 50% as basal + 25% active tillering stage and panicle initiation stage). And lowest grain yield (q ha^{-1}) ware recorded under the treatment T_9 (Control) (23.58, 25.10 and 24.33 q ha^{-1}) respectively years. Also reported the similar results Gaikwad *et al*., (2023), Dhawne *et al*., (2023), Chandana *et al*., (2021).

3.11 Straw Yield (q ha^{-1})

The data pertaining on straw yield (q ha^{-1}) is presented in Table 4. The results demonstrated that different nano fertilizers significantly influenced straw yield (q ha^{-1}) during the years 2023, 2024, and pooled basis.

The straw yield (q ha^{-1}) was recorded significantly higher during the year 2023, 2024 and pooled basis with application of treatment T_2 which included (T_1+ Two spray of nano urea at active tillering stage and Panicle initiation) (58.80, 60.45 and 59.62 q ha^{-1}) respectively years. Which ware being at par treatment T_1 (125% RDN through Urea (50% as basal + 25%

Table 4. Effect of nano urea as influence by yield characteristic in grain and straw yield of transplanted rice

Treatment	Grain yield (q ha^{-1})			Straw yield (q ha^{-1})			Biological yield (q ha^{-1})			Harvest index (%)		
	2023	2024	Pooled	2023	2024	Pooled	2023	2024	pooled	2023	2024	pooled
T_1: 125% RDN through Urea (50% as basal + 25% at active tillering stage and Panicle initiation).	47.25	49.14	48.19	58.10	60.00	59.04	105.35	109.13	107.24	44.85	45.02	44.93
T_2: T_1+ Two spray of Nano Urea at active tillering stage and Panicle initiation.	47.94	49.66	48.79	58.80	60.45	59.62	106.74	110.11	108.42	44.91	45.10	45.01
T_3: 100% RDN through Urea in three splits (50% as basal + 25% at active tillering stage and Panicle initiation stage).	45.96	47.90	46.92	56.88	59.61	58.24	102.84	107.52	105.17	44.69	44.54	44.62
T_4: T_3 + Two spray of Nano Urea at active tillering stage and panicle initiation stage (@ 4 ml/ litre of water.	46.78	48.22	47.49	57.56	59.94	58.74	104.34	108.16	106.24	44.83	44.58	44.71
T_5: 75% RDN through Urea (50% as basal + 25% active tillering stage and panicle initiation stage)	42.86	45.06	43.96	53.26	56.75	55.00	96.13	101.81	98.96	44.60	44.26	44.43
T_6: T_5 + Two spray on Nano Urea at active tillering stage and panicle initiation stage	43.56	45.89	44.72	53.92	57.50	55.70	97.48	103.39	100.43	44.69	44.38	44.53
T_7: 50% RDN through Urea (50% basal + 25% at active tillering stage and panicle initiation stage)	37.15	39.20	38.17	48.98	51.54	50.26	86.13	90.73	88.43	43.13	43.20	43.17
T_8: T_7+ Two spray of Nano Urea at active tillering stage and panicle initiation stage	38.95	41.05	39.99	51.05	52.36	51.71	90.01	93.41	91.71	43.27	43.94	43.61
T_9: Control	23.58	25.10	24.33	36.50	39.02	37.76	60.08	64.12	62.10	39.14	39.16	39.15
SE(d)±	4.99	5.15	4.92	4.74	4.75	4.52	5.73	5.73	5.54	0.82	0.87	0.80
CD (p=0.05)	10.59	10.91	10.42	10.05	10.08	9.58	12.15	12.14	11.74	1.74	1.84	1.69

at active tillering stage and Panicle initiation), T_4 (T_3 + Two spray of Nano Urea at active tillering stage and panicle initiation stage (@ 4 ml/ litre of water), T_3 (100% RDN through Urea in three splits (50% as basal + 25% at active tillering stage and Panicle initiation stage), T_6 **(**T_5 + Two spray on Nano Urea at active tillering stage and panicle initiation stage) and T_5 (75% RDN through Urea 50% as basal + 25% active tillering stage and panicle initiation stage). And lowest straw yield (q ha^{-1}) ware recorded under the treatment T_9 (Control) (36.50, 39.02 and 37.76 q ha^{-1}) respectively years. Also reported the similar results Alam *et al*., (2010), Midde *et al.,* (2022).

3.12 Biological Yield (q ha^{-1})

The data pertaining on biological yield (q ha^{-1}) is presented in Table 4. The results demonstrated that different nano fertilizers significantly influenced biological yield (q ha^{-1}) during the years 2023, 2024, and pooled basis.

The biological yield (q ha^{-1}) was recorded significantly higher during the year 2023, 2024 and pooled basis with application of treatment T_2 which included (T_1+ Two spray of nano urea at active tillering stage and Panicle initiation) (106.74, 110.11, and 108.42 q ha^{-1}) respectively years. Which ware being at par treatment T_1 (125% RDN through Urea (50% as basal + 25% at active tillering stage and Panicle initiation), T_4 (T_3 + Two spray of Nano Urea at active tillering stage and panicle initiation stage (@ 4 ml/ litre of water), T_3 (100% RDN through Urea in three splits (50% as basal + 25% at active tillering stage and Panicle initiation stage), T_6 **(**T_5 + Two spray on Nano Urea at active tillering stage and panicle initiation stage) and T_5 (75% RDN through Urea 50% as basal + 25% active tillering stage and panicle initiation stage). And lowest biological yield (q ha^{-1}) ware recorded under the treatment T_9 (Control) (60.08, 64.12, and 62.10 q ha^{-1}) respectively years. Also reported the similar results Alam *et al*., (2010), Midde *et al.,* (2022).

3.13 Harvest Index (%)

The data pertaining on harvest index (%) is presented in Table 4. The results demonstrated that different nano fertilizers significantly influenced harvest index (%) during the years 2023, 2024, and pooled basis.

The harvest index (%) was recorded significantly higher during the year 2023, 2024 and pooled basis with application of treatment T_2 which included (T_1+ Two spray of nano urea at active tillering stage and Panicle initiation) (44.91, 45.10 and 45.01 %) respectively years. Which ware being at par treatment T_1 (125% RDN through Urea (50% as basal + 25% at active tillering stage and Panicle initiation), T_4 (T_3 + Two spray of Nano Urea at active tillering stage and panicle initiation stage (@ 4 ml/ litre of water), T_3 (100% RDN through Urea in three splits (50% as basal + 25% at active tillering stage and Panicle initiation stage), T_6 **(**T_5 + Two spray on Nano Urea at active tillering stage and panicle initiation stage) and T_5 (75% RDN through Urea 50% as basal + 25% active tillering stage and panicle initiation stage). And lowest harvest index (%) ware recorded under the treatment T_9 (Control) (39.14, 39.16 and 39.15 %) respectively years. Also reported the similar results Mehta and Bharat (2019).

4. CONCLUSION

During two years of trials in the sandy loam soils of central Uttar Pradesh, Student's Instructional Farm of Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, the treatment involving T_2 (T_1+ Two spray of Nano Urea at active tillering stage and Panicle initiation). proved to be most effective, resulting in the highest recorded values for all yield attributes and yield parameter *i.e.* number of panicles (m^{-2}), total number of tillers (m^{-2}), length of panicle (cm), number of productive tillers (m^{-2}), test weight (1000 grains) (g.), total number of grains $panicles^{-1}$, number of filled grains $panicles^{-1}$, grain yield (q ha^{-1}), straw yield (q ha^{-1}), biological yield (q ha^{-1}), harvest index (%) of rice.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that they have no known competing financial interests or non-financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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