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# Study of Nano Urea application under graded n rates on growth, productivity and nitrogen use efficiency of transplanted rice (*Oryza sativa* L.)

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**ABSTRACT:** A field experiment was convened at A-2 block (Rice Agronomy block) Norman E. Borlaug Crop Research Centre of G. B. Pant University of Agriculture and Technology, Pantnagar on a sandy loam soil (*Mollisol*) during *Kharif* 2022 for the experiment of "study the impact of Nano Urea application under graded N rates on growth, productivity and nitrogen use efficiency of transplanted rice". The soil was neutral in pH (7.5), medium in Organic Carbon content (0.64%), Low in Nitrogen (177.6 Kg/ha), moderate in Phosphorus (19.6 Kg/ha), and medium in Potassium (198.3 Kg/ha). The study was conducted using Randomized block design in 9 treatments and each has 3 replications and the Rice variety Dhan-24(PD-24) was used. The treatments embodied of $\mathbf{T_1}$ (100% RDN), $T_2$ (75% RDN), $T_3$ (50% RDN + 2 Foliar Spray of Nano Urea (AT, PI)), $T_4$ (75% RDN + 2 Foliar Spray of Nano Urea (AT, PI)), $T_5$ (100% RDN + 2 Foliar Spray of Nano Urea (AT, PI)), $T_6$ (50% RDN + 2 Foliar Spray of Urea (AT, PI)), $T_7$ (75% RDN + 2 Foliar Spray of Urea (AT, PI)), $T_8$ (100% RDN (1/3 + 1/3 + 1/3 ) + 2 Foliar Spray of Nano Urea (AT, PI)) and $T_9$ (Control).The growth parameters were considerably influenced by different treatment at 30, 60, and 90 days after Transplanting (DAT) and upon reaching the maturity. At initial stages of crop growth, $T_1$ has reported significantly higher plant height, tiller m$^{-2}$, dry matter accumulation and SPAD value. But as the crop grew farther, the treatment T8 had much higher growth parameters that were comparable to those of T5**.** The yield attributing characters (number of panicles m$^{-2}$, number of filled spikelet per panicle, number of unfilled spikelet per panicle, spikelet sterility, and grain weight per panicle) were significantly affected by various treatments. However, panicle length, number of spikelet per panicle and 1000 grain weight were found to be non- significant. The treatment $T_8$ reported significantly higher yield attributes which were at par with $T_5$. The treatment $T_8$ also reported the highest grain, straw, and biological yields which were 11.9%, 8.5%, and 9.9% higher than $T_1$ respectively. However, harvest index was not significantly affected by various treatments. The economics of rice production was also significantly affected by various treatments reporting the highest gross returns, net returns and B/C ratio in $T_8$.

**Key words:** Nano Urea, Pant Dhan-24, RDN, FS-NU

Rice, a fundamental dietary component, serves as a primary food source for over 3 billion individuals residing in tropical, sub-tropical, and temperate regions across the globe. Currently, rice holds the third rank in terms of production and the second rank in terms of cultivation area worldwide. According to the Food and Agriculture Organization (FAO) report of 2021, a staggering 756.74 million tons of rice were harvested in 143 countries, covering an extensive area of 164.19 million hectares in the year 2019. According to the OECD-FAO report 2022, the per capita consumption of rice in Asia is projected to witness a gradual increase from 76.9 kg per capita per year during the period of 2019-21 to 78.7 kg per capita by the year 2031. Additionally, the report also highlights that rice production in India is anticipated to experience a notable surge, rising from 123.16 million metric tons (mt) in the period of 2019-21 to 149.73 million mt by the year 2031. These estimations provide valuable insights into the future trends and dynamics of rice consumption and production in the region. About 90% of the global rice cultivation is limited to Asia, China is the largest producer of rice in the world contributing 30% of the global rice production (Carter *et al.,* 2017). Following China, India is second largest rice producer globally. India managed to produce 122.27 million hectares, achieving a productivity rate of 2.71 t/ha during 2020-21 (DES, 2021). Currently, there are more than 110,000 cultivated varieties of rice that vary in nutritional content and quality (Fukagawa and Ziska, 2019).

Nitrogenous fertilizer application is necessary to meet the crop's demand as majority of the rice growing regions (RGRs) of India are deficient in available N (Ghosh and Hasan, 1980). The natural cycle of N including lightening and biological nitrogen fixation by cyanobacteria and diazotrophic bacteria can meet only a part of high N required for intensive crop production. About, 93% of the Indian soils fall under low and medium soil status (Dey and Sekhon, 2016).

The total consumption of N in India was 20.40 mt in 2020-21 of which 13.75 mt was domestically produced. Of the total consumption of N, 16.30 mt (79.9%) is contributed by Urea (FAI, 2021). Urea is extensively utilized as a solid nitrogen fertilizer across the globe. It is highly soluble, dry material used in many ways to provide N for plant growth. The total consumption of Urea in India was 35.04 mt during 2020-21 of which 9.82 mt was imported draining a significant amount of forex reserves.

Nano-fertilizers includes nanoscale fertilizers (nanosized reformulation of a fertilizer input reduced in size, using mechanical or chemical methods), nanoscale additives (nanomaterials are added to bulk (>100 nm scale) product) and nanoscale coatings (nano-thin films or nano-porous materials used for the controlled release of the nutrient input) (Mastronardi *et al.*, 2015). Nano fertilizers experience lesser losses due to controlled release and target specific delivery compared to the conventional fertilizer applications to the soil (Wang *et al.*, 2016).

Nano urea contains nitrogen particles at nanoscale (18-30 nm) with significantly more surface area (10,000 times over 1 mm urea prill) and the higher number of particles (55,000 nitrogen particles over 1 mm urea prill). This Nano urea featuring a 20 nm pore size of can effectively penetrate the cell wall and reach up to the plasma membrane (Kumar *et al.,* 2021).

The present method employed by farmers for N management in their fields involves applying 50% of the fertilizer as a basal application, while the remaining 50% is split into two doses during the active tillering (AT) and panicle initiation (PI) stages of the crop as top dressing. Nano urea has the potential to replace these two later splits by being applied as a foliar spray. However, it is crucial to compare the potential benefits of nano urea with the previous recommendation of a 2% foliar spray of urea during the later stages of crop growth.

## MATERIALS AND METHODS

A field experiment took place at A2 block (Rice Agronomy section) within the Norman E. Borlaug Crop Research Centre of G. B. Pant University of Agriculture and Technology Pantnagar, Udham Singh Nagar, Uttarakhand. The center is situated at latitude of 29.60°N and a longitude of 79.36°E. The elevation of the location is 243.83 meters above sea level. The climate in this region falls within the sub-tropical, sub-humid climatic zone, characterized by cool winters and hot and humid summers. The maximum temperature ranges from 31.4°C to 45.2°C. The experimental field has been following a rice-wheat crop rotation since 1966. Wheat is cultivated as a commercial crop during the *Rabi* season prior to the experimental rice crop.

The present study was carried out in randomized block design with nine treatments and three replications. The treatments are $T_1$ (100% RDN), $T_2$ (75% RDN), $T_3$ (50% RDN + 2 Foliar Spray of Nano Urea (AT, PI)), $T_4$ (75% RDN + 2 Foliar Spray of Nano Urea (AT, PI)), $T_5$ (100% RDN + 2 Foliar Spray of Nano Urea (AT, PI)), $T_6$ (50% RDN + 2 Foliar Spray of Urea (AT, PI)), $T_7$ (75% RDN + 2 Foliar Spray of Urea (AT, PI)), $T_8$ (100% RDN (1/3 + 1/3 + 1/3 ) + 2 Foliar Spray of Nano Urea (AT, PI)) and $T_9$ (Control). The experiment had total 27 plots (experimental units) each of 5.0m length and 4.0m width. In this study semi dwarf rice variety Pant Dhan – 24 was used for the experiment.

### *Growth Studies*

The observations on growth and development parameters such as plant height, tiller count, dry matter accumulation were recorded at 30, 60, 90 days after transplanting and at harvest stage. From the third and fourth row corners of each plot, a total of sixteen hills were tagged, and the mean of those observations was reported.

**Plant height**

The plant height was recorded from tagged plants with the help of meter scale from the base of the hill to the tip of longest leaf up to heading and then up to tip of the panicle at maturity. The mean values are reported as height (cm) of the plant at 30, 60, 90 days and at harvest stage.

**Dry matter accumulation**

Four hills from outside the net plot area were clipped randomly just above the ground level with help of sickle. The plant samples were dried in drier at 65 ± 5°C till the sample attained a constant weight. The average weight was multiplied with no. of hills in one $m^2$ area and dry matter accumulation reported as $g/m^2$.

*Yield attributing characters*

**Number of panicles**

The number of panicles was counted from the tagged plants. The values were averaged and multiplied with total number of hills in one $m^2$ area to obtain number panicles per $m^2$.

**Effective tillers**

The 16 hills, used for counting of number of tillers were used for counting the number of effective tillers. A tiller bearing a panicle was treated as effective tiller.

**Panicle length**

From the sampling rows, 10 panicles were selected for determination of panicle length. The panicle length was measured from the base of the first branch of rachis to the tip of the panicle. The mean of ten panicles was reported as panicle length (cm).

**Filled grains per panicle**

Ten panicles taken for panicle length were manually threshed and total number of filled (F) and unfilled grains (U) were counted. Then average of ten panicles was reported.

**Grain weight per panicle**

Ten panicles taken for panicle length were manually threshed. The weight of the grains was recorded and divided by a total number of panicles and reported as grain weight per panicle.

**1000-grain weight**

The grain sample was drawn from produce of each net plot after weighing for yield. Then thousand grains were counted and their weight was reported in gram.

**Unfilled spikelets per panicle**

Ten panicles were manually threshed and total number of filled and unfilled grains was counted. Then average of ten panicles was reported as unfilled grains per panicle.

**Spikelet sterility**

Spikelet sterility is reported as the ratio of unfilled grains to the total grains multiplied by 100.

$$\text{Spikelet sterility} = \frac{\text{Unfilled grains (U)}}{\text{Filled grain (F)} + \text{Unfilled grain (U)}} \times 100$$

*Yield*

**Biological yield**

The crop was harvested from the net plot. The harvested biomass was sundried for 4-6 days. The total biomass was weighed and reported biological yield (kg/ha).

**Grain yield**

The total produce of net plot was threshed by Pullman thresher. The weight of cleaned grains was recorded by using grain moisture meter and adjusted at 14 per cent moisture. It was converted into grain yield kg/ha.

**Straw yield**

It was determined after deducting grain weight from the total produce weight and then reported as Kg/ha.

**Harvest index (HI)**

It was calculated using the following formula:

$$\mathbf{HI(\%)} = \frac{\textbf{Grain yield (kg ha)}}{\textbf{Biological yield (kg ha)}} \times 100$$

## RESULTS AND DISCUSSION

*Growth studies*

**Plant Height**

The data pertaining to the plant height at different stages of crop growth are summarized in Table 1, and the analysis of variance is graphically represented in Fig. 1.

At 30 DAT, the maximum plant height was observed in $T_1$ (100% RDN) which was significantly higher than other treatments except $T_5$ (100% RDN + 2 FS-NU). The higher plant height may be attributed to higher basal dose of N fertilizer which led to a higher availability of nitrogen for early growth. The minimum height was observed in $T_9$ (Control). The minimum height may be attributed to no fertilization. At 60 DAT, the highest plant height was observed in $T_8$ (100% RDN (1/3 + 1/3 +1/3) + 2 FS-NU) which was statistically at par with $T_5$ (100% RDN + 2 FS-NU) and the minimum height was observed in $T_9$ (Control). The treatment $T_8$ (100% RDN (1/3 + 1/3 +1/3) reported the highest rate of increase (81.4%) in plant height between 30 and 60 days after transplanting. The higher plant height in $T_8$ (100% RDN (1/3 + 1/3 +1/3) + 2 FS-NU) was attained due to a higher rate of growth which may be attributed to enhanced vegetative growth due to higher N availability by foliar application of nano urea (NU) in addition to top dressing during the active tillering (AT) and panicle initiation (PI) stage. And $T_8$ (100% RDN (1/3 + 1/3 +1/3) + 2 FS-NU) also received a higher rate of split application, i.e. leading to higher uptake by the plant.

At 90 DAT, the maximum plant height was observed in $T_8$ (100% RDN (1/3+1/3+1/3) + 2 FS-NU) which was statistically at par with $T_5$ (100% RDN + 2 FSNU). The plant height in $T_8$ (100% RDN (1/3+1/3+1/3) + 2 FS-NU) and $T_5$ (100% RDN + 2 FS-NU) was 5.4% and 3.9% higher than $T_1$ (100% RDN) respectively. The minimum height was observed in $T_9$ (Control).

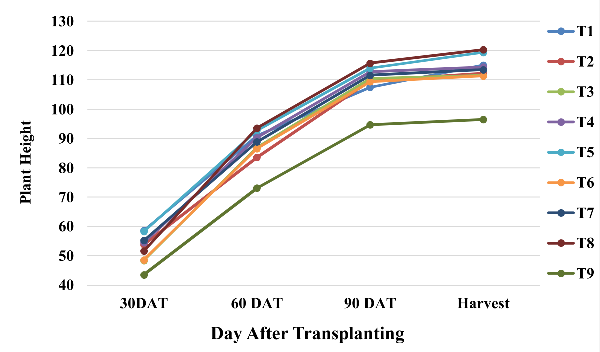

**Fig. 1: Plant height of rice at different stages as influenced by different treatments**

At maturity, the maximum plant height was observed in $T_8$ (100% RDN (1/3+1/3+1/3) + 2 FS-NU) which was statistically at par with $T_5$ (100% RDN + 2 FSNU). The plant height in $T_8$ was 4.5% higher compared to $T_1$ (100% RDN). The minimum height was observed in $T_9$ (Control).

## Dry Matter Accumulation

At 30 DAT, the highest dry matter accumulation (g $m^{-2}$) was observed in $T_1$ (100% RDN) which was statistically

**Table 1: Plant height of rice at different stages as influenced by different treatments**

| | Treatment | Plant height | | | |
|---|---|---|---|---|---|
| | | 30DAT | 60 DAT | 90 DAT | Harvest |
| $T_1$ | 100% RDN | 58.6 | 91.0 | 107.5 | 115.1 |
| $T_2$ | 75% RDN | 53.8 | 83.6 | 109.7 | 112.2 |
| $T_3$ | 50% RDN+ 2 FS-NU | 48.4 | 86.9 | 110.4 | 111.5 |
| $T_4$ | 75% RDN+ 2 FS-NU | 54.5 | 90.3 | 112.8 | 114.4 |
| $T_5$ | 100% RDN+ 2 FS-NU | 58.3 | 92.8 | 114.0 | 119.4 |
| $T_6$ | 50% RDN+ 2 FS-NU | 48.6 | 86.6 | 109.4 | 111.4 |
| $T_7$ | 75% RDN+ 2 FS-NU | 55.2 | 88.9 | 111.6 | 113.5 |
| $T_8$ | 100% RDN $\left(\frac{1}{3}+\frac{1}{3}+\frac{1}{3}\right)$ + 2 FS-NU | 51.6 | 93.6 | 115.7 | 120.3 |
| $T_9$ | Control | 43.5 | 73.1 | 94.7 | 96.5 |
| SEm± | | 0.65 | 0.52 | 0.74 | 1.08 |
| CD 5% | | 1.96 | 1.59 | 2.23 | 3.26 |

**Table 2: Dry matter accumulation (g/m2) at different stages in rice as influenced by different treatments**

| | Treatment | Dry Matter Accumulation | | | |
|---|---|---|---|---|---|
| | | 30DAT | 60 DAT | 90 DAT | Harvest |
| $T_1$ | 100% RDN | 142.5 | 544.4 | 983.3 | 1070.4 |
| $T_2$ | 75% RDN | 128.1 | 466.9 | 924.2 | 1022.5 |
| $T_3$ | 50% RDN+ 2 FS-NU | 104.4 | 475.0 | 923.5 | 1025.0 |
| $T_4$ | 75% RDN+ 2 FS-NU | 125.8 | 538.9 | 962.5 | 1060.0 |
| $T_5$ | 100% RDN+ 2 FS-NU | 141.6 | 566.1 | 114.0 | 119.4 |
| $T_6$ | 50% RDN+ 2 FS-NU | 103.8 | 461.7 | 910.0 | 1001.7 |
| $T_7$ | 75% RDN+ 2 FS-NU | 126.0 | 518.1 | 930.0 | 1030.8 |
| $T_8$ | 100% RDN(1/3+1/3+1/3)+ 2 FS-NU | 120.0 | 569.9 | 1036.7 | 1143.3 |
| $T_9$ | Control | 58.8 | 247.2 | 460.0 | 541.7 |
| SEm± | | 2.36 | 13.75 | 12.31 | 13.59 |
| CD 5% | | 7.08 | 39.50 | 36.90 | 40.76 |

at par with $T_5$ (100% RDN + 2 FS-NU) but varied among different treatments. The minimum DMA was observed in $T_9$ (Control). The higher dry matter suggests a better photosynthetic performance by the crop plants in $T_1$ (100% RDN).

At 60 DAT, the highest DMA was observed in $T_8$ (100% RDN (1/3+1/3+1/3) + 2 FS-NU) which was statistically at par with $T_5$ (100% RDN + 2 FS-NU). The minimum DMA was observed in $T_9$ (Control). The treatment $T_8$ (100% RDN (1/3+1/3+1/3) + 2 FSNU) reported an increase of 4.68% in dry matter accumulation compared to 100% RDN at 60 days after transplanting which may be attributed to higher rate of dry matter accumulation between 30 and 60 DAT. While $T_5$ (100% RDN + 2 FS-NU) reported an increase of 3.98% in dry matter accumulation compared to 100% RDN.

At 90 DAT, the highest DMA was observed in $T_8$ (100% RDN (1/3+1/3+1/3) + 2 FS-NU) which was statistically at par with $T_5$ (100% RDN + 2 FS-NU). The minimum DMA was observed in $T_9$ (Control). The treatment $T_8$ (100% RDN (1/3+1/3+1/3) + 2 FS-NU) reported an increase of 5.43% in dry matter accumulation compared to 100% RDN while $T_5$ (100% RDN + 2 FS-NU) reported an increase of 4.41% in dry matter accumulation compared to 100% RDN at 90 days after transplanting.

At maturity, the highest DMA was observed in $T_8$ (100% RDN (1/3+1/3+1/3) + 2 FS-NU) which was statistically at par with $T_5$ (100% RDN + 2 FS-NU). The minimum DMA was observed in $T_9$ (Control). The treatment $T_8$ (100% RDN (1/3+1/3+1/3) + 2 FSNU) reported an increase of 6.81% in dry matter accumulation compared to 100% RDN while $T_5$ (100% RDN + 2 FS-NU) reported an increase of 5.61% in dry matter accumulation compared to 100% RDN at maturity.

Similar results were also reported by Tarafdar *et al.* (2014) and Vafa *et al.* (2015) due to the application of nanofertilizers. The higher dry matter production by plants may be attributed to enhanced nitrogen assimilation, enhanced crude protein, soluble carbohydrates, photo-reduction activities of PSII and the electron transport chain, and scavenging of reactive oxygen species (ROS) (Morteza *et al.*, 2013). A significant improvement in growth characteristics (plant height, tiller number per unit area, and DMA) may have resulted from the application of conventional and nano fertilizers together. This may have increased photosynthesis

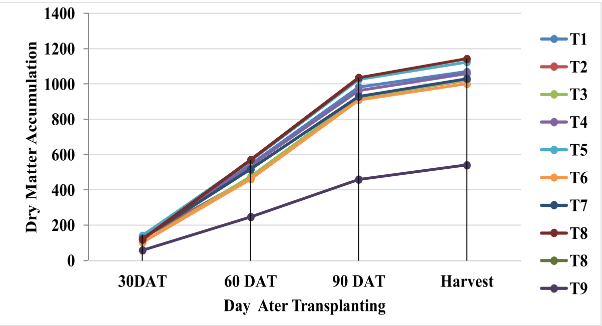

**Fig. 2: Dry matter accumulation (g/m$^2$) at different stages in rice as influenced by different treatments**

and the production of photosynthates, which in turn increased the number of panicles per unit area and contributed to dry matter accumulation. The studies by Jyothi and Hebsur (2017) and Benzon *et al.* (2015) also reported 63.8% and 15.3% higher dry matter accumulation, respectively, in combinations of full recommended rates of conventional fertilizer and nano fertilizer (FRR-CF + FRRNF) compared to full recommended rates of conventional fertilizers.

***Yield attributing***

Data regarding the number of panicles m$^{-2}$, number of spikelet per panicle, number of filled spikelet per panicle, and 1000 grain weight have been summarized in Table 3.

**Number of Panicles**

Data related to number of panicles m$^{-2}$ was significantly affected by different treatments. The highest number of panicles m$^{-2}$ observed was 205 in $T_8$ (100% RDN (1/3+1/3+1/3) + 2 FS-NU) which were 15.8% higher than 100% RDN. The number of panicles in $T_8$ were statistically similar to $T_5$ (100% RDN + 2 FS-NU) which recorded 202 panicles m$^{-2}$. The number of panicles m$^{-2}$ in $T_5$ (100% RDN + 2 FS-NU) 15.8% higher than 100% RDN. While the minimum number of panicles/m$^2$ were reported in $T_9$ (Control) which is due to no fertilization.

Each yield component is determined at a particular stage in the plant's life (Tanaka and Matsushima, 1970). In the transplanting rice cultivation, the number of panicles per square meter is largely dependent on tillering performance, which is largely determined by 10 days after the maximum tiller number stage (Yoshida, 1981). Hence, higher number of panicles m$^{-2}$ may be attributed to higher number of tillers reported in the treatment $T_8$ (100% RDN (1/3+1/3+1/3) + 2 FS-NU) and $T_5$ (100% RDN + 2 FS-NU).

**Number of spikelets per panicle**

The data related to number of spikelets per panicle were not significantly affected by different treatments. However, maximum number of spikelets per panicle (133) were observed in $T_8$ (100% RDN (1/3+1/3+1/3) + 2 FS-NU) and lowest number of spikelets per panicle (129) were observed in $T_9$ (control). The number of spikelets per panicle is determined during the reproductive growth stage. Early in the reproductive growth, the maximum number of spikelets is determined by the differentiation of branches and spikelets. After spikelet differentiation, some spikelets may degenerate (Yoshida, 1981).

**Number of filled spikelets per panicle**

Data related to number of filled spikelets per panicle was significantly affected by different treatments. However, maximum number of filled spikelet per panicle (112) were observed in $T_8$ (100% RDN (1/3+1/3+1/3) + 2 FS-NU) and lowest number of filled spikelet per panicle (100) was observed in $T_9$ (control). The percentage of filled spikelets is determined before, at, and after heading. The crop season received heavy rains during reproductive period of the crop as evident from the weather data. The reproductive stage coincided with highest rain during month of September hence a lower rate of filled spikelets per panicle was observed.

**Thousand grain weight**

The data related to 1000 grain weight were not significantly affected by different treatments. However, maximum 1000 grain weight (26.7 g) was observed in $T_8$ (100% RDN (1/3+1/3+1/3) + 2 FSNU) and lowest 1000 grain weight (23.5 g) was observed in $T_9$ (control). The 1,000-grain weight is a stable varietal character because the grain size is rigidly controlled by the size of the hull (Yoshida, 1981). The absorption of N from basal dose is almost finished before tillering stage while absorption of N from top dressing or foliar spray is extremely vigorous during the panicle formation stage. The foliar application of N during PI stage has led to higher N availability to plant thus contributing in grain filling. Those treatments receiving foliar application of nano urea reported comparatively higher thousand grain weight compared to others.

***Yield***

Data regarding grain, straw, biological yield and harvest index (HI) have been summarized in Table

3 and graphically represented in Fig 3. The grain, straw and biological yield were significantly affected by different treatment.

### Grain yield

The highest grain yield was observed in $T_8$ (100% RDN (1/3+1/3+1/3) + 2 FSNU) which was statistically at par with $T_5$ (100% RDN + 2 FS-NU). The lowest grain yield was found in control treatment $T_9$ (Control). The treatment 100% RDN (1/3+1/3+1/3) + 2 FS-NU reported 11.9% higher grain yield compared to 100% RDN and 100% RDN + 2 FS-NU reported 9.01% higher grain yield compared to 100% RDN.

### Straw yield

The highest straw yield was observed in $T_8$ (100% RDN (1/3+1/3+1/3) + 2 FSNU) which was statistically at par with $T_5$ (100% RDN + 2 FS-NU), $T_4$ (75% RDN + 2 FS-NU), and $T_1$ (100% RDN). The lowest straw yield was found in $T_9$ (Control). The treatment 100% RDN (1/3+1/3+1/3) + 2 FS-NU reported 3.65% higher straw yield compared to 100% RDN explaining the fact that the foliar application of nano urea at later stages of crop growth (AT and PI) has contributed for grain yield.

Increased availability of nitrogen supply enhances the rate of dry matter accumulation via the synthesis of photo-assimilates in the rice leaves which is the center of plant growth during vegetative stage and later translocation of the assimilates to the reproductive organs (Yadav, 2007).

### Biological yield

The highest biological yield was observed in $T_8$ (100% RDN (1/3+1/3+1/3) + 2 FS-NU) which is statistically at par with $T_5$ (100% RDN + 2 FS-NU) and $T_4$ (75% RDN + 2 FS-NU). The lowest grain yield was found in control treatment $T_9$ (Control). The treatment 100% RDN (1/3+1/3+1/3) + 2 FS-NU reported 7.07% higher biological yield compared to 100% RDN while 100% RDN + 2 FS-NU reported 4.48% higher biological yield compared to 100% RDN.

Similar results were also reported by Janmohammadi *et al.* (2016). The higher biological yield may be attributed to higher biomass accumulation resulting from higher plant height, tiller/m$^2$ and dry matter accumulation. Nitrogen top dressing along with foliar N application (NU, U) affects the yield through active photo synthesis during ripening. Nitrogen absorption during panicle initiation (PI) stage help leaves to be greener after heading and thereby contribute to active photosynthesis for grain production (Yoshida, 1981).

### Harvest Index

The highest value for harvest index (HI) was observed in $T_8$ (100% RDN (1/3+1/3+1/3)+2 FS-NU) followed by $T_5$ (100% RDN + 2 FS-NU). Among different treatments, the comparable values of HI reveal that the increase in economic biomass (i.e., grain yield) was proportionate to total biomass accumulation; however, the treatments in which nano urea was sprayed have reported a higher harvest index.

**Table 3: Yield attributing characters as influenced by different treatments in rice**

| Treatment | | No. of Panicle (m$^{-2}$) | No. of spikelet per panicle | No. of filled spikelet per panicle | 1000 grain wt. (g) |
|---|---|---|---|---|---|
| $T_1$ | 100% RDN | 177 | 131 | 108 | 25.6 |
| $T_2$ | 75% RDN | 157 | 130 | 103 | 26.1 |
| $T_3$ | 50% RDN+ 2 FS-NU | 166 | 132 | 104 | 25.9 |
| $T_4$ | 75% RDN+ 2 FS-NU | 182 | 132 | 109 | 26.2 |
| $T_5$ | 100% RDN+ 2 FS-NU | 202 | 132 | 111 | 26.6 |
| $T_6$ | 50% RDN+ 2 FS-NU | 163 | 130 | 102 | 24.7 |
| $T_7$ | 75% RDN+ 2 FS-NU | 174 | 131 | 106 | 26.1 |
| $T_8$ | 100% RDN+ 2 FS-NU | 205 | 133 | 112 | 26.7 |
| $T_9$ | Control | 120 | 129 | 100 | 23.5 |
| SEm± | | 5.37 | 0.99 | 1.45 | 0.70 |
| CD 5% | | 16.23 | NS | 4.40 | NS |

**Table 4: Grain, straw, and biological yields and Harvest Index in rice as influenced by different treatments**

| Treatment | | Yield | | | |
|---|---|---|---|---|---|
| | | Grain | Straw | Biological | HI (%) |
| $T_1$ | 100% RDN | 4856 | 6894 | 11438 | 41.3 |
| $T_2$ | 75% RDN | 4044 | 5622 | 9667 | 41.8 |
| $T_3$ | 50% RDN+ 2 FS-NU | 3880 | 5570 | 9450 | 41.1 |
| $T_4$ | 75% RDN+ 2 FS-NU | 4875 | 6562 | 11750 | 42.6 |
| $T_5$ | 100% RDN+ 2 FS-NU | 5294 | 6962 | 12277 | 43.1 |
| $T_6$ | 50% RDN+ 2 FS-NU | 3694 | 5369 | 9063 | 40.8 |
| $T_7$ | 75% RDN+ 2 FS-NU | 4254 | 6038 | 10292 | 41.3 |
| $T_8$ | 100% RDN+ 2 FS-NU | 5435 | 7147 | 12581 | 43.2 |
| $T_9$ | Control | 2184 | 2941 | 5125 | 42.6 |
| SEm± | | 88 | 131 | 91 | 0.85 |
| CD 5% | | 264 | 395 | 272 | NS |

**Table 5: Economics of rice as influenced by different treatments**

| Treatment | | Cost of cultivation | Gross return | Net return | B:C ratio |
|---|---|---|---|---|---|
| $T_1$ | 100% RDN | 44089.91 | 99059.00 | 54969.09 | 1.25 |
| $T_2$ | 75% RDN | 43651.57 | 82505.25 | 38853.68 | 0.89 |
| $T_3$ | 50% RDN+ 2 FS-NU | 45813.17 | 79152.00 | 33338.83 | 0.73 |
| $T_4$ | 75% RDN+ 2 FS-NU | 45901.57 | 99458.50 | 53556.93 | 1.17 |
| $T_5$ | 100% RDN+ 2 FS-NU | 46339.91 | 107988.25 | 61648.34 | 1.33 |
| $T_6$ | 50% RDN+ 2 FS-NU | 44296.78 | 75352.50 | 31055.72 | 0.70 |
| $T_7$ | 75% RDN+ 2 FS-NU | 44734.98 | 86776.50 | 42041.52 | 0.94 |
| $T_8$ | 100% RDN(1/3+1/3+1/3)+ 2 FS-NU | 46339.91 | 110865.50 | 64525.59 | 1.39 |
| $T_9$ | Control | 37621.19 | 44557.00 | 6935.81 | 0.18 |
| SEm± | | | 1798.66 | 1798.66 | 0.04 |
| CD 5% | | | 5438.8 | 5438.8 | 0.12 |

Lemraski *et al.* (2017) reported the highest harvest index (HI) in combination with conventional and nano-fertilizers. An increase in the harvest index would mean an improvement in grain yield. It seems that the function of nanofertilizer at the reproductive stage of rice was only supplemental. Nonetheless, it was evident that nanofertilizer application enhanced the harvest index, but the improvement was non-significant.

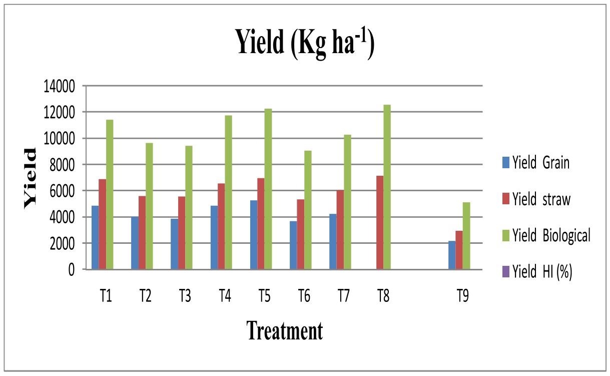

**Fig 3: Yield in Rice as influenced by different treatments**

### ***Economic studies***

The data pertaining to economic parameters of crop production like cost of cultivation, gross return and benefit cost ratio due to different nutrient management practices.

### Cost of cultivation

The highest cost of cultivation (Rs. 46339.91/ha) in rice was observed under $T_5$ (100% RDN + 2 FS-NU) and $T_8$ (100% RDN (1/3+1/3+1/3) + 2 FS-NU) followed by $T_4$ (75% RDN + FS of NU) that recorded Rs. 45901.57/ha. Considering the lowest cost of cultivation (Rs. 37621.19/ha) under treatment $T_9$ (Control).

### Gross return

The highest gross return in rice (Rs. 116810/ha) was found under treatment $T_8$ (100% RDN (1/3+1/3+1/3) + 2 FS-NU) followed by $T_5$ (100% RDN + 2 FS-NU) which recorded gross returns Rs. 116643/ha. Considering lowest gross return in rice (Rs. 42024/

ha) was observed under treatment $T_9$ (Control).

### B: C Ratio

The highest benefit cost ratio (1.39) was observed under the treatment $T_8$ (100% RDN (1/3+1/3+1/3) + 2 FS-NU) which might be due to higher productivity. Lowest benefit cost ratio (0.18) was observed under the treatment $T_9$ (Control) might be due to high cost of cultivation and low net return compare to other treatment.

## CONCLUSION

Based on the findings of the present study, it can be concluded that the nano urea application is superior as compared to the foliar application of urea, giving better results in combination with conventional fertilizers. The application of 100% RDN (1/3+1/3+1/3) + 2 FS-NU combinations stood out as the most efficient in terms of yield and economics. However, being a one-year study, further investigation to evaluate the physiology, mechanisms, and long-term effects of nano urea (NU) would be a better proposition.

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