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## Effect of nano urea on growth and yield of wheat (*Triticum aestivum* L.) under irrigated condition

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### Abstract

This investigation was conducted on wheat during the *rabi* season of 2020-21 to check the effect of nano urea on plant growth and yield of crop. Various nutrient management practices included different nano urea based treatments along with RDN application at tillering and jointing stages compared with sole application of Recommended Dose of Nitrogen (RDN) & no fertilizer (control) to study the effect of growth and yield of irrigated wheat crop. The study depicted that the treatment T<sub>3</sub> included RDN along with two sprays of nano urea at two growth stages showed comparable results with T<sub>4</sub> included RDN with two sprays of urea (5%) at the same growth stages. The findings indicated that nano urea had significant effects on various developmental stages. These treatments had a significant impact on different plant growth and yield attributing parameters. Therefore, it is suggested that the two sprays of nano urea at the jointing and tillering stages, in conjunction with 100% RDN shows markable effect of crop's growth and yield.

**Keywords:** Nano urea, RDN, growth stage, yield, wheat crop

### 1. Introduction

Wheat (*Triticum aestivum* L.) stands as the predominant *rabi* season cereal crop in our nation. As a hexaploid (6n = 42) annual crop within the Poaceae or Gramineae family, it plays a pivotal role in sustaining approximately 4.5 billion people, contributing 20% to their daily protein and calorie intake. In India, it holds the position of the second most crucial cereal crop, following rice. Almost one-third of the global population relies on wheat as a staple food, making it the most widely consumed cereal worldwide. The cultivation of wheat spans about 225.62 million hectares (m ha) globally, yielding 685.60 million tonnes (m ton) and achieving a productivity rate of 3039 kg ha<sup>-1</sup> (Shingne *et al.* 2017) <sup>[19]</sup>. Major wheat-producing nations include China, India, USA, Russia, and France. Within India, wheat is cultivated across 31.45 m ha, producing 107.59 m tons, with a productivity rate of approximately 3421 kg ha<sup>-1</sup>. The primary wheat-producing states in India include Uttar Pradesh, Haryana, Punjab, and Rajasthan. Punjab boasts the highest productivity, followed by Uttar Pradesh and Haryana (Maurya, 2021) <sup>[10]</sup>. The rank of Bihar is 6<sup>th</sup> in wheat production, cultivating an area of 2.25 m ha, producing 5.90 m tons, with a productivity rate of 2626 kg ha<sup>-1</sup> (Directorate of Economics and Statistics, 2022) <sup>[4]</sup>. Conversely, nano fertilizers represent a significant source of nutrients in agriculture, enhancing crop growth, yield, and quality parameters. They improve nutrient use efficiency and reduce cultivation costs, proving highly effective in precision agriculture for precise nutrient management. Nano fertilizers offer increased surface area for various metabolic reactions in plants, elevating photosynthesis rates, and consequently, enhancing dry matter production and crop yield (Qureshi *et al.*, 2018) <sup>[11]</sup>. Notably, Nano urea, produced by various industries, holds the potential to revolutionize agriculture in the country. India has taken a global lead by initiating commercial production of Nano urea, becoming the second-largest consumer globally. Nano urea is the sole nano fertilizer approved by the Government of India and is included in the Fertilizer Control Order, 1985. The nano-formulations of nitrogen fertilizer may effectively minimize nitrogen losses through leaching, emissions, and soil microbial immobilization.

(Baruah and Dutta, 2009)<sup>[2]</sup>.

## 2. Materials and Methodology

The field experiment was conducted during the 2020–21 Rabi season at the wheat farm of the experimental station at Bihar Agricultural University, Sabour, Bhagalpur, Bihar. The geography and fertility of the experimental plots were uniform. Bihar Agricultural University, Sabour, Bhagalpur, is situated in the Middle Gangetic plain region of Agro-climatic Zone III (A) in Bihar. Its coordinates are 25°50' N latitude and 87°19' E longitude, with an elevation of 37.19 meters above mean sea level.

Bhagalpur experienced a cool and dry climate with bright sunny days throughout the crop season. The maximum temperature ranged from 20.3 to 36.3 °C, while the minimum temperature fluctuated between 10.8 and 22.8 °C during the rabi crop season of 2020-21. The lowest temperature was recorded in January 2022. Meteorological observatory data indicated that the crops received a well-distributed total rainfall of 57.7 mm during the experimentation period.

### 2.1 Calendar of operations

The schedule of cultural operations performed in wheat during 2020-21 is given in Table 1.

**Table 1:** Cultural operations performed during experimentation.

| Particulars of operations                   | Date of operation |
|---------------------------------------------|-------------------|
| Land preparation                            | 24. 11. 2021      |
| Layout, levelling and bunding of plot       | 25. 11. 2021      |
| Basal application of fertilizers            | 29. 11. 2021      |
| Sowing                                      | 29. 11. 2021      |
| Top dressing of Nitrogen through urea       | 25. 12. 2022      |
| Weeding                                     | 07. 01. 2022      |
| Nano urea and urea spray at tillering stage | 15. 01. 2022      |
| Nano urea and urea spray at jointing stage  | 05. 02. 2022      |
| Harvesting                                  | 20. 04. 2022      |
| Threshing                                   | 25. 04. 2022      |
| Irrigations                                 |                   |
| 1. CRI                                      | 20. 12. 2021      |
| 2. Booting                                  | 20. 01. 2022      |
| 3. Milking stage                            | 13. 02. 2022      |

### 2.2 Variety

This study examines the Karan Vandana (DBW 187) wheat variety, which was released for irrigated timely sown conditions in the North Eastern Plain Zone. The zone encompasses East Bengal, Jharkhand, Assam, Eastern Uttar Pradesh, and Bihar.

### 2.3 Fertilizer application

The recommended fertilizer doses were applied as a basal application in the experimental plots, comprising urea (46% N), di-ammonium phosphate (16% N, 46% P<sub>2</sub>O<sub>5</sub>), and muriate of potash (60% K<sub>2</sub>O). The full dose of phosphate (60 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup>) as DAP and potash (40 kg K<sub>2</sub>O ha<sup>-1</sup>) as MOP was administered at the time of sowing. The recommended nitrogen dose was split into two applications: half at sowing as a basal application and the remaining half as top dressing during the tillering and jointing stage. For treatments with 75% and 50% of the recommended dose of nitrogen (RDN), the nitrogen requirement was determined after calculating the nitrogen content of DAP.

The experiment was arranged in a Randomized Block Design (RBD) with various nutrient management practices, namely: T<sub>1</sub> (RDN + water spray at tillering and jointing stage), T<sub>2</sub> (RDN + one spray of nano urea at tillering stage), T<sub>3</sub> (RDN + two sprays

of nano urea at tillering and jointing), T<sub>4</sub> (RDN + two sprays of urea (5%) at tillering and jointing), T<sub>5</sub> (75% RDN + water spray at tillering and jointing), T<sub>6</sub> (75% RDN + one spray of nano urea at tillering stage), T<sub>7</sub> (75% RDN + two sprays of nano urea at tillering and jointing), T<sub>8</sub> (75% RDN + two sprays of urea (5%) at tillering and jointing), T<sub>9</sub> (50% RDN + water spray at tillering and jointing), T<sub>10</sub> (50% RDN + one spray of nano urea at tillering), T<sub>11</sub> (50% RDN + two sprays of nano urea at tillering and jointing), T<sub>12</sub> (50% RDN + two sprays of urea (5%) at tillering and jointing), and T<sub>13</sub> (Control).

The data collection process encompassed the measurement of various parameters including plant height, tiller count, dry matter accumulation, and leaf area index. Plant height measurements were conducted at 25, 50, 75, and 100 days after sowing (DAS), as well as at the harvest stage, on randomly selected plants within each plot. Utilizing statistical analysis, the mean height for each plot was determined. Furthermore, the average number of tillers per square meter was ascertained by counting the tillers at three points along a 1-meter row within each plot at sequential growth stages (25, 50, 75, 100 DAS, and at the harvest stage).

The plant samples, each measuring 25 centimetres, were taken from two different sites in the border rows of the subplots. To calculate the total dry matter production, the samples were air-dried and then placed in an oven at 60 ± 5 °C until a consistent weight was achieved. At every stage of the plants' growth, the dry weight of each plant per square meter was measured. Following Watson's (1952) recommendation, the leaf area index (LAI) was calculated using the formula: Leaf Area Index (LAI) = Leaf Area (cm<sup>2</sup>) / Ground area (cm<sup>2</sup>) × 100. The leaf area index was then measured using a Ceptometer at 25, 50, 75, and 100 DAS.

## 3. Result and Discussion

### 3.1 Effect of nano urea on growth parameters of wheat

#### 3.1.1 Plant height

Table 2 presents data on the mean plant height (cm) at various growth stages, ranging from 25 days after sowing (DAS) to the maturity stage of wheat. The analysis of variance (ANOVA) reveals significant differences in plant height, except at 25 DAS, owing to varying levels of nutrient management throughout all growth stages. As the plant progressed in its growth, wheat plant height exhibited a steady increase up to 100 DAS, reaching its peak at harvest. The most rapid increase occurred between 50 and 75 DAS, followed by a gradual decrease in the rate of growth.

Results indicate that nano urea induced significant variations in wheat plant height at 50, 75, 100 DAS, and maturity stage. Among the treatments, those receiving recommended dose of nitrogen (RDN) along with two nano urea sprays at tillering and jointing stages (T<sub>3</sub>) displayed consistently taller plants during all growth stages, except at 25 DAS, where it was statistically comparable to the tallest plant height achieved with the treatment receiving RDN along with two sprays of urea 5% at tillering and jointing stages (T<sub>4</sub>). The control treatment, which received no fertilizer, resulted in the minimum plant height at 50, 75, 100 DAS, and maturity stage.

The observed increase in plant height with escalating nano urea doses may be attributed to the sustained nutrient supply, thereby facilitating various metabolic processes. Nano-fertilizers play a pivotal role in enhancing the physiological and biochemical processes of crops. They serve to optimize nutrient availability, bolster metabolic processes, and incite meristematic activities, thereby resulting in escalated apical growth and expanded

photosynthetic area.

The application of nano nitrogen (N) through foliar spraying has been observed to enhance growth characteristics by promoting nutrient availability. This is attributed to the efficient penetration of nano N through the stomata of leaves during gas exchange.

These findings align with previous studies by Sharma *et al.* (2022) <sup>[18]</sup>, Rajasekar *et al.* (2015) <sup>[13]</sup>, Sahu *et al.* (2022) <sup>[15]</sup>, Kumar *et al.* (2014) <sup>[6]</sup> in Rice Crop, Yadav *et al.* (2023) <sup>[21]</sup> in Wheat crop, and Sarkar *et al.* (2023) <sup>[17]</sup> in wheat crop.

**Table 2:** Effect of nano urea on plant height (cm) of wheat.

| Treatments      |                                  | Plant height (cm) |        |        |         |             |
|-----------------|----------------------------------|-------------------|--------|--------|---------|-------------|
|                 |                                  | 25 DAS            | 50 DAS | 75 DAS | 100 DAS | At maturity |
| T <sub>1</sub>  | RDN + water spray                | 24.06             | 43.17  | 77.8   | 91      | 92.8        |
| T <sub>2</sub>  | RDN + one spray of nano urea     | 23.73             | 44.32  | 83.53  | 91.92   | 93.27       |
| T <sub>3</sub>  | RDN + two spray of nano urea     | 24.12             | 44.75  | 83.96  | 93.13   | 94.64       |
| T <sub>4</sub>  | RDN + two spray of urea (5%)     | 23.77             | 44.94  | 84.33  | 94.1    | 95.38       |
| T <sub>5</sub>  | 75% RDN+ water spray             | 23.35             | 41.03  | 78.12  | 87      | 85.12       |
| T <sub>6</sub>  | 75% RDN+ one spray of nano urea  | 22.93             | 42.15  | 80.07  | 88.37   | 87.23       |
| T <sub>7</sub>  | 75% RDN + two spray of nano urea | 22.75             | 42.37  | 81.18  | 87.85   | 88.92       |
| T <sub>8</sub>  | 75% RDN + two spray of urea (5%) | 23.39             | 43.28  | 84.1   | 88.13   | 89.23       |
| T <sub>9</sub>  | 50% RDN + water spray            | 21.29             | 36.25  | 71.12  | 76.99   | 80.97       |
| T <sub>10</sub> | 50% RDN+ one spray of nano urea  | 22.4              | 38.25  | 73.95  | 77.5    | 81.58       |
| T <sub>11</sub> | 50% RDN+ two spray of nano urea  | 21.73             | 38.95  | 74.16  | 78.83   | 82.77       |
| T <sub>12</sub> | 50% RDN +two spray of urea (5%)  | 23.23             | 39.77  | 76.52  | 80.3    | 83.32       |
| T <sub>13</sub> | Control                          | 20.62             | 31.33  | 66.28  | 71.04   | 76.68       |
| GM              |                                  | 22.87             | 40.81  | 78.09  | 85.09   | 87.07       |
| SEm (±)         |                                  | 1.68              | 2.05   | 2.69   | 2.51    | 2.93        |
| CD              |                                  | NS                | 5.98   | 7.84   | 7.33    | 8.55        |

### 3.1.2 Tillers per meter square

Table 3 presents data on the number of tillers per square meter at various growth stages. The findings reveal a significant impact of nano urea on wheat, influencing tiller density at all progressive growth stages. Notably, there was a substantial increase in tiller count from 25 to 75 days after sowing (DAS), followed by a subsequent decline until maturity. Except for the 25 DAS stage, treatments involving recommended dose of nitrogen (RDN) with two applications of nano urea during tillering and jointing stages (T<sub>3</sub>) demonstrated significantly higher tiller density compared to other treatments. Specifically, T<sub>3</sub> showed statistically comparable results to the treatment with RDN along with two sprays of urea 5% during tillering and

jointing stages (T<sub>4</sub>), recording the highest tiller density.

The control treatment, devoid of any fertilizer, exhibited the minimum number of tillers per square meter at 50, 75, 100 DAS, and maturity stages. This outcome may be attributed due to the prolonged nutrient release capability of nano fertilizers, ensuring sustained nutrient supply and positively influencing plant growth. The foliar application of nano nitrogen was found to enhance nitrogen uptake through both leaves and roots. This could potentially help move more synthesized carbohydrates into amino acids and proteins, leading to increased cell division and elongation. Previous studies on wheat crops by Rawate *et al.* (2022) <sup>[14]</sup>, Yadav *et al.* (2023) <sup>[21]</sup>, and Sarkar *et al.* (2023) <sup>[17]</sup> have reported similar findings.

**Table 3:** Effect of nano urea on no of tillers at different growth stages of wheat.

| Treatments      |                                  | Tillers (m <sup>-2</sup> ) |        |        |         |             |
|-----------------|----------------------------------|----------------------------|--------|--------|---------|-------------|
|                 |                                  | 25 DAS                     | 50 DAS | 75 DAS | 100 DAS | At maturity |
| T <sub>1</sub>  | RDN + water spray                | 192.34                     | 372.38 | 390.08 | 366.93  | 298.67      |
| T <sub>2</sub>  | RDN + one spray of nano urea     | 195.79                     | 374.22 | 398.33 | 371.27  | 302.69      |
| T <sub>3</sub>  | RDN + two spray of nano urea     | 188.55                     | 375.81 | 402.65 | 372.73  | 305.59      |
| T <sub>4</sub>  | RDN + two spray of urea (5%)     | 177.05                     | 380.94 | 409.88 | 375.60  | 318.52      |
| T <sub>5</sub>  | 75% RDN+ water spray             | 189.83                     | 360.08 | 375.52 | 346.54  | 288.85      |
| T <sub>6</sub>  | 75% RDN+ one spray of nano urea  | 190.29                     | 361.08 | 379.57 | 354.25  | 279.15      |
| T <sub>7</sub>  | 75% RDN + two spray of nano urea | 190.63                     | 363.53 | 386.17 | 360.85  | 282.90      |
| T <sub>8</sub>  | 75% RDN + two spray of urea (5%) | 192.63                     | 365.71 | 398.93 | 365.08  | 295.58      |
| T <sub>9</sub>  | 50% RDN + water spray            | 172.49                     | 273.68 | 305.37 | 288.85  | 220.71      |
| T <sub>10</sub> | 50% RDN+ one spray of nano urea  | 189.76                     | 283.73 | 311.84 | 291.03  | 232.38      |
| T <sub>11</sub> | 50% RDN+ two spray of nano urea  | 172.12                     | 293.22 | 324.59 | 294.00  | 253.64      |
| T <sub>12</sub> | 50% RDN +two spray of urea (5%)  | 174.64                     | 308.17 | 335.25 | 298.44  | 268.27      |
| T <sub>13</sub> | Control                          | 168.99                     | 262.06 | 294.22 | 235.52  | 185.59      |
| GM              |                                  | 184.24                     | 336.51 | 362.49 | 332.39  | 271.73      |
| SEm (±)         |                                  | 11.18                      | 18.38  | 18.74  | 14.28   | 12.21       |
| CD at 5%        |                                  | 32.64                      | 53.64  | 54.70  | 41.67   | 35.63       |

### 3.1.3 Leaf area index (LAI)

Table 4 presents the data on the mean Leaf Area Index (LAI) at various growth stages, illustrating the impact of nano urea on wheat. The analysis indicates significant variations among treatments attributed to the influence of nano urea on wheat. LAI

showed a notable increase from 25 to 75 Days after Sowing (DAS), followed by a decline from 75 to 100 DAS. The gradual rise in wheat LAI correlated with the crop's aging, with the most substantial growth acceleration occurring between 50 and 75 DAS. The findings reveal that nano urea significantly affected

LAI at 50, 75, and 100 DAS, excluding 25 DAS. However, Treatment T<sub>3</sub>, which involved two nano urea sprays at the tillering and jointing stages alongside Recommended Dose of Nitrogen (RDN), demonstrated statistical parity with the maximum LAI observed in Treatment T<sub>4</sub>. This latter treatment involved two sprays of a 5% urea solution at the tillering and jointing stages along with RDN. The control treatment, receiving no fertilizer, exhibited the lowest LAI at 50, 75, 100 DAS, and maturity stage.

The augmentation of leaf area positively impacted the plant's ability to capture sunlight effectively, potentially leading to increased assimilate production and consequently supporting the crop's growth and development [12, 13, 14]. Consequently, an ample nitrogen supply resulted in increased plant height and greater LAI. Similar observations were reported by Singh *et al.* (2023)<sup>[20]</sup> in wheat crops, as well as by Sharma *et al.* (2022)<sup>[18]</sup> and Yadav *et al.* (2023)<sup>[21]</sup> in wheat cultivation.

**Table 4:** Effect of nano urea on leaf area index of wheat

| Treatments      |                                  | Leaf area index (LAI) |        |        |         |
|-----------------|----------------------------------|-----------------------|--------|--------|---------|
|                 |                                  | 25 DAS                | 50 DAS | 75 DAS | 100 DAS |
| T <sub>1</sub>  | RDN + water spray                | 0.80                  | 2.20   | 3.77   | 3.28    |
| T <sub>2</sub>  | RDN + one spray of nano urea     | 0.82                  | 2.24   | 3.83   | 3.41    |
| T <sub>3</sub>  | RDN + two spray of nano urea     | 0.81                  | 2.26   | 3.90   | 3.83    |
| T <sub>4</sub>  | RDN + two spray of urea (5%)     | 0.83                  | 2.28   | 3.93   | 3.87    |
| T <sub>5</sub>  | 75% RDN + water spray            | 0.82                  | 2.11   | 3.59   | 2.71    |
| T <sub>6</sub>  | 75% RDN + one spray of nano urea | 0.79                  | 2.12   | 3.64   | 2.85    |
| T <sub>7</sub>  | 75% RDN + two spray of nano urea | 0.82                  | 2.14   | 3.69   | 3.00    |
| T <sub>8</sub>  | 75% RDN + two spray of urea (5%) | 0.82                  | 2.19   | 3.81   | 3.15    |
| T <sub>9</sub>  | 50% RDN + water spray            | 0.81                  | 1.66   | 2.85   | 2.37    |
| T <sub>10</sub> | 50% RDN + one spray of nano urea | 0.79                  | 1.84   | 3.06   | 2.44    |
| T <sub>11</sub> | 50% RDN + two spray of nano urea | 0.80                  | 1.86   | 3.17   | 2.50    |
| T <sub>12</sub> | 50% RDN + two spray of urea (5%) | 0.80                  | 1.89   | 3.19   | 2.60    |
| T <sub>13</sub> | Control                          | 0.79                  | 1.60   | 2.35   | 1.99    |
| GM              |                                  | 0.81                  | 2.02   | 3.44   | 2.92    |
| SEm (±)         |                                  | 0.03                  | 0.13   | 0.19   | 0.24    |
| CD at 5%        |                                  | NS                    | 0.38   | 0.56   | 0.71    |

### 3.1.4 Dry matter accumulation

Table 5 presents the data on mean dry matter accumulation at progressive growth stages, ranging from 25 days after sowing (DAS) to crop maturity, with a focus on the impact of nano urea on wheat. The analysis of wheat crop dry matter accumulation data indicates the significance of all treatments influenced by nano urea. Among the applied treatments, T<sub>3</sub> receiving two sprays of nano urea at the tillering and jointing stages, along with recommended dose of nitrogen (RDN) demonstrated statistical at par with T<sub>4</sub>, which involved two sprays of a 5% urea solution at the tillering and jointing stages along with RDN. Both T<sub>3</sub> and T<sub>4</sub> exhibited maximum dry matter accumulation in

plants, with no significant variations observed at 25 DAS. In contrast, the control treatment, which received no fertilizer, showed the minimum dry matter accumulation at 50, 75, 100 DAS, and at the maturity stage.

The observed increase in dry matter can be attributed to the escalating nitrogen levels facilitated by foliar application of urea, leading to a significant difference in total dry matter production. This effect may be linked to an elevated photosynthetic rate and increased leaf area, as suggested by Rahman *et al.* (2014)<sup>[12]</sup>. Similar findings were reported by Al-Shamary *et al.* (2022)<sup>[1]</sup> in wheat crop, Sharma *et al.* (2022)<sup>[18]</sup> in rabi maize, and Samui *et al.* (2022)<sup>[16]</sup>.

**Table 5:** Effect of nano urea on dry matter accumulation of wheat.

| Treatments      |                                  | Dry matter accumulation (g m <sup>-2</sup> ) |        |        |         |             |
|-----------------|----------------------------------|----------------------------------------------|--------|--------|---------|-------------|
|                 |                                  | 25 DAS                                       | 50 DAS | 75 DAS | 100 DAS | At maturity |
| T <sub>1</sub>  | RDN + water spray                | 83.66                                        | 237.85 | 375.38 | 532.01  | 556.82      |
| T <sub>2</sub>  | RDN + one spray of nano urea     | 81.34                                        | 243.31 | 380.61 | 533.33  | 561.67      |
| T <sub>3</sub>  | RDN + two spray of nano urea     | 83.55                                        | 245.09 | 387.19 | 540.96  | 566.77      |
| T <sub>4</sub>  | RDN + two spray of urea (5%)     | 79.49                                        | 249.01 | 393.72 | 555.52  | 571.19      |
| T <sub>5</sub>  | 75% RDN + water spray            | 78.18                                        | 223.64 | 362.30 | 481.96  | 528.45      |
| T <sub>6</sub>  | 75% RDN + one spray of nano urea | 78.75                                        | 230.91 | 364.89 | 487.30  | 538.71      |
| T <sub>7</sub>  | 75% RDN + two spray of nano urea | 81.88                                        | 232.86 | 370.41 | 459.10  | 540.33      |
| T <sub>8</sub>  | 75% RDN + two spray of urea (5%) | 81.14                                        | 242.12 | 373.63 | 497.08  | 561.78      |
| T <sub>9</sub>  | 50% RDN + water spray            | 76.69                                        | 190.74 | 340.38 | 415.63  | 468.15      |
| T <sub>10</sub> | 50% RDN + one spray of nano urea | 78.09                                        | 200.04 | 352.24 | 425.45  | 483.76      |
| T <sub>11</sub> | 50% RDN + two spray of nano urea | 77.92                                        | 208.30 | 357.17 | 436.96  | 490.77      |
| T <sub>12</sub> | 50% RDN + two spray of urea (5%) | 80.09                                        | 215.41 | 358.82 | 371.93  | 495.55      |
| T <sub>13</sub> | Control                          | 80.22                                        | 179.35 | 292.17 | 318.77  | 421.89      |
| GM              |                                  | 80.08                                        | 222.97 | 362.22 | 465.85  | 521.99      |
| SEm (±)         |                                  | 4.35                                         | 9.59   | 17.01  | 22.44   | 22.06       |
| CD at 5%        |                                  | NS                                           | 28.00  | 49.64  | 65.49   | 64.38       |

### 3.1.5 Crop growth rate (CGR)

The mean calculated values of crop growth rate (g m<sup>-2</sup> day<sup>-1</sup>) that

was recorded at 25 to 50 DAS, 50 to 75 DAS, 75 to 100 DAS and 100 DAS to maturity stages and associated data was

depicted in Table 6. Generally, the value of CGR was declined with time and maximum value achieved at 25-50 DAS. The effect of nano urea on CGR of wheat crop that did not show any significant variation among the treatments. During initial stage

(25-30 DAS), the maximum ( $6.78 \text{ g m}^{-2} \text{ day}^{-1}$ ) and minimum ( $3.97 \text{ g m}^{-2} \text{ day}^{-1}$ ) value of CGR was mentioned in the treatments T4 and T13 respectively. While at 100-maturity stage, the range of CGR that varied between 3.25 and 0.99 among the treatments.

**Table 6:** Effect of nano urea on crop growth rate of wheat

| Treatments      |                                  | Crop growth rate ( $\text{g m}^{-2} \text{ day}^{-1}$ ) |           |            |                  |
|-----------------|----------------------------------|---------------------------------------------------------|-----------|------------|------------------|
|                 |                                  | 25-50 DAS                                               | 50-75 DAS | 75-100 DAS | 100-Maturity DAS |
| T <sub>1</sub>  | RDN + water spray                | 6.17                                                    | 5.50      | 6.27       | 0.99             |
| T <sub>2</sub>  | RDN + one spray of nano urea     | 6.48                                                    | 5.49      | 6.11       | 1.13             |
| T <sub>3</sub>  | RDN + two spray of nano urea     | 6.46                                                    | 5.68      | 6.15       | 1.03             |
| T <sub>4</sub>  | RDN + two spray of urea (5%)     | 6.78                                                    | 5.79      | 6.47       | 1.24             |
| T <sub>5</sub>  | 75% RDN + water spray            | 5.82                                                    | 5.55      | 4.79       | 1.86             |
| T <sub>6</sub>  | 75% RDN + one spray of nano urea | 6.09                                                    | 5.36      | 4.90       | 2.06             |
| T <sub>7</sub>  | 75% RDN + two spray of nano urea | 6.04                                                    | 5.50      | 3.55       | 3.25             |
| T <sub>8</sub>  | 75% RDN + two spray of urea (5%) | 6.44                                                    | 5.26      | 4.94       | 2.59             |
| T <sub>9</sub>  | 50% RDN + water spray            | 4.56                                                    | 5.99      | 3.01       | 2.10             |
| T <sub>10</sub> | 50% RDN + one spray of nano urea | 4.88                                                    | 6.09      | 2.93       | 2.33             |
| T <sub>11</sub> | 50% RDN + two spray of nano urea | 5.21                                                    | 5.95      | 3.19       | 2.15             |
| T <sub>12</sub> | 50% RDN + two spray of urea (5%) | 5.41                                                    | 5.74      | 1.28       | 4.94             |
| T <sub>13</sub> | Control                          | 3.97                                                    | 4.51      | 1.06       | 4.12             |
| SEm ( $\pm$ )   |                                  | 0.30                                                    | 0.81      | 1.07       | 1.14             |
| CD at 5%        |                                  | NS                                                      | NS        | NS         | NS               |

## 3.2 Yield

### 3.2.1 Grain yield

The perusal data of mean economic yield (grain yield) of *rabi* season crop of wheat have been documented in Table 7. The grain yield of wheat varied significantly with different level of nitrogen fertilizer along with foliar spray of water and nano urea took place. The associated data showed that significantly higher grain yield ( $4492 \text{ kg ha}^{-1}$ ) was recorded under treatment T3 where two sprays of nano urea at tillering and jointing stage, along with 100% RDN, which was statistically at par with the highest yield ( $4573 \text{ kg ha}^{-1}$ ) obtained in the treatment T4; where two sprays of 5% urea solution applied at tillering and jointing stage along with 100% RDN. The treatments T3 (RDN along with two spray of nano urea) T2, T1, T7 and T8 was found to be statistically at par with the highest value obtained from the treatment T4. These treatments (T4 and T3) produced significantly superior result over T5, T6, T9, T10, T11, T12 and T13. The application of 100, 75 and 50% RDN along with two foliar spray of nano urea (T3, T7 and T11) augmented the grain yield by 52.89, 40.10 and 17.22% more over T13 (control). It is also evident from the table that 75% RDN along with two spray of nano urea at tillering and jointing stage was equally effective with 100% RDN in increasing the grain yield.

The associated data showed that significantly highest grain yield ( $4492 \text{ kg ha}^{-1}$ ) was recorded with treatment T3 where two sprays of nano urea at tillering and jointing stage, along with 100% RDN, which was statistically at par with T4. This may be due the application of nano fertilizer in conjugation with traditional nitrogen fertilizers improves nutrient absorption efficiency, enhanced photosynthesis, increases nutrient translocation, and

ultimately increases the economic and biological yield. When growth and yield parameters are increasing by Nano urea spray, overall yield will also increase. These results are close with results of Kumar *et al.* (2020) [6]; Khalil *et al.* (2019) [5]; (Ma *et al.* 2010) [9] and Liu and Liao (2008) [8].

### 3.2.2 Straw yield

The effect of nano urea on straw yield of wheat had significant effect (Table 6). The data depicts that the higher value ( $5235.67 \text{ kg ha}^{-1}$ ) of straw yield was obtained in treatment T3 i.e., receiving RDN along with two spray of nano urea at tillering and jointing and the highest value ( $5319.33 \text{ kg ha}^{-1}$ ) was obtained under treatment T4 receiving RDN along with two spray of 5% urea. Treatments T1, T2, T3, T5, T6, T7 and T8 were found to be statistically at par with the highest value (T4). While straw yield noted under the treatment T1 ( $5078.20 \text{ kg ha}^{-1}$ ) was at par with the straw yield obtained under the treatment T7 ( $5174.97 \text{ kg ha}^{-1}$ ), so we can curtail 25% RDN with the application of 75% RDN along with two spray of nano urea. The control treatment (T13) where no fertilizer had applied performed inferior and contributed in lesser straw yield ( $3809 \text{ kg ha}^{-1}$ ) among all the treatments.

### 3.2.3 Harvest index (HI)

The HI calculated from grain and straw yield was statistically analysed and presented in the Table 6. The different doses of nitrogen and foliar spray of nano urea did not exert significant effect on harvest index in the study. It was recorded that the highest 46.40 and lowest 42.98% HI was noted and in the treatment T2 and T12 respectively.

| Treatments     |                                  | Grain Yield ( $\text{kg ha}^{-1}$ ) | Straw yield ( $\text{kg ha}^{-1}$ ) | Harvest Index (%) |
|----------------|----------------------------------|-------------------------------------|-------------------------------------|-------------------|
| T <sub>1</sub> | RDN + water spray                | 4210.00                             | 5078.20                             | 45.29             |
| T <sub>2</sub> | RDN + one spray of nano urea     | 4423.33                             | 5098.32                             | 46.40             |
| T <sub>3</sub> | RDN + two spray of nano urea     | 4492.33                             | 5235.67                             | 46.08             |
| T <sub>4</sub> | RDN + two spray of urea (5%)     | 4573.33                             | 5319.33                             | 46.25             |
| T <sub>5</sub> | 75% RDN + water spray            | 3927.33                             | 5033.33                             | 43.72             |
| T <sub>6</sub> | 75% RDN + one spray of nano urea | 4030.00                             | 5142.97                             | 43.98             |
| T <sub>7</sub> | 75% RDN + two spray of nano urea | 4116.67                             | 5174.97                             | 44.29             |
| T <sub>8</sub> | 75% RDN + two spray of urea (5%) | 4240.33                             | 5230.68                             | 44.66             |
| T <sub>9</sub> | 50% RDN + water spray            | 3254.67                             | 4244.80                             | 43.47             |

|                 |                                  |         |         |       |
|-----------------|----------------------------------|---------|---------|-------|
| T <sub>10</sub> | 50% RDN + one spray of nano urea | 3391.67 | 4494.17 | 43.30 |
| T <sub>11</sub> | 50% RDN + two spray of nano urea | 3444.33 | 4533.33 | 43.10 |
| T <sub>12</sub> | 50% RDN + two spray of urea (5%) | 3469.00 | 4606.67 | 42.98 |
| T <sub>13</sub> | Control                          | 2938.33 | 3809.00 | 43.87 |
| SEm (±)         |                                  | 148.43  | 194.87  | 1.63  |
| CD at 5%        |                                  | 433.23  | 568.79  | NS    |

#### 4. Conclusion

This study conclude that applying two sprays of nano urea at the jointing and tillering stages, in conjunction with 100% Recommended Dose of Nitrogen (RDN), resulted higher yield compared to using only RDN. Moreover, this study also accomplish that employing two foliar sprays of nano urea allowed for 25% reduction in the recommended fertilizer dose.

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