

EFFECT OF NANO UREA ON GROWTH, YIELD AND NITROGEN USE EFFICIENCY OF IRRIGATED WHEAT (*Triticum aestivum* L.)

ABSTRACT

In the rabi season of 2021-22, the field study was conducted at Bihar Agricultural University, Bhagalpur (Bihar), to see the effects of nano urea on growth attributes, yield and nitrogen use efficiency of irrigated wheat (*Triticum aestivum* L.). Thirteen different treatments with three replications are used in Randomized block design. Treatments involved different levels of the recommended dose of nitrogen along nano-urea applied at tillering and jointing stages. The results showed that 100% and 75% RDN with two sprays of nano urea (T_3 and T_7 respectively) significantly improved the yield attributes and yield. This study gave the highest grain yield of 4573 kg h⁻¹ for RDN + two spray of urea (5%) in T_4 and 4492 kg h⁻¹ from RDN + two spray of nano urea (T_3). The present study has also shown that application of 75% RDN with nano urea resulted in the highest NUE of 10.20 kg kg⁻¹. This means that nano-urea can be used with conventional urea without an adverse effect on high productivity of wheat.

Keywords- Nano Urea, Urea spray 5%, NUE, Bihar, Irrigated Wheat.

1. INTRODUCTION

Wheat (*Triticum aestivum* L.) is a rabi (annual) crop in India, ranking first among global cereals and serving as a staple food for one third of global population. It has caryopsis type of fruit and its grain contains 78% carbohydrates, 11-12% protein, 1.80-2.00% fat, 1.8% minerals, and 2.20% fiber, along with essential vitamins such as thiamine (B₁), riboflavin (B₂), niacin (B₃), and small amounts of vitamin A. In India, wheat is cultivated across 31.45 million hectares, producing 107.59 million tons with a productivity of 3421 kg ha⁻¹. Bihar ranks 6th in cultivating wheat on 2.25 million hectares, producing 5.90 million tons, and a productivity of 2626 kg ha⁻¹. Traditional wheat cultivation heavily relies on urea as a nitrogen source, but its application often results in significant nitrogen losses due to leaching, volatilization, and denitrification, along with increased transportation costs due to its bulkiness. Thus, Nano Urea (particle size 20-50 nm) has emerged as an innovative and eco-friendly alternative, offering enhanced nutrient use efficiency, reduced cultivation costs, and improved crop growth, yield, and quality. India has pioneered its commercial production, becoming the second-largest consumer globally. A 500 ml bottle of Nano Urea providing 4% (w/v) of nitrogen is equivalent to 45 kg urea bag. Nano Urea is not only efficient but also eco-friendly, contributing to the preservation of soil health. When applied, Nano Urea is easily absorbed by the plant through stomata and other openings on the leaves, quickly assimilated, and efficiently distributed throughout the plant via the phloem. Nitrogen is stored in cell

vacuole and gradually released ensuring continuous supply for growth and development for efficient nitrogen utilization.

2. MATERIAL AND METHODS

The research was performed during the Rabi season of 2021-21 at the Research Farm of Bihar Agricultural University, Sabour (Bhagalpur) located in Agro-climatic Zone III A of Bihar. The region experiences an average annual rainfall of 1167 mm. and January, being the coldest month of the year, recorded a minimum temperature range of 5 to 10 °C. The soil was characterized by low organic carbon content (0.46%), low available nitrogen (162.0 kg ha⁻¹), medium available phosphorus (22.54 kg ha⁻¹), and available potassium (151.0 kg ha⁻¹); having a pH of 7.5 and EC- 0.26 dS m⁻¹.

Randomized Block Design (RBD) is used in the experiment with three replications. The fertilizer dose applied was 150:60:40 kg ha⁻¹ of N: P₂O₅: K₂O. The variety used for the study was DBW187 (Karan Vandana). The experiment consisted of 13 different treatments. Treatment T₁- involved recommended dose of nitrogen (RDN) combined with a water spray at tillering and jointing stages. Treatment T₂- RDN + one spray of Nano Urea at the tillering stage. Treatment T₃- RDN + two sprays of Nano Urea at tillering and jointing stages, Treatment T₄- RDN + two sprays of 5% urea solution at the same growth stages. Treatment T₅- reduced the nitrogen dose to 75% of RDN combined with a water spray at tillering and jointing stages, Treatment T₆-75% RDN + one spray of Nano Urea at tillering. Treatment T₇- 75% RDN + two sprays of Nano Urea at tillering and jointing stages, and Treatment T₈- involved 75% RDN with two sprays of 5% urea solution at the both stages. Treatment T₉- reduced the nitrogen dose to 50% of RDN combined with a water spray at tillering and jointing stages. Treatment T₁₀- 50% RDN + one spray of Nano Urea at tillering stage, Treatment T₁₁ included 50% RDN + two sprays of Nano Urea at tillering and jointing. Treatment T₁₂- 50% RDN with two sprays of 5% urea solution at the same stages, and Treatment T₁₃- served as the control. 60 kg Phosphate (P₂O₅) ha⁻¹ as SSP and 40 kg potash (K₂O) ha⁻¹ as MOP were fully applied as a basal dose at the time of sowing. The recommended dose of nitrogen was applied in two splits as basal dose (at the time of sowing) and the remaining half as top dressing during the tillering and jointing stages.

Crop growth attributes were measured at 25, 50, 75, and 100 DAS. Plants' height was recorded from the base to top using a meter scale. The number of tillers meter⁻² was counted for each plot. For dry matter accumulation, plants above 0.25 m were collected and dried in an oven at 60°C until a constant weight was achieved at each growth stage. Leaf area index (LAI) was determined using a Ceptometer, calculated as total leaf area (cm²) = $\frac{\text{Total leaf area (cm}^2\text{)}}{\text{ground area (cm}^2\text{)}}$. and Crop growth rate (CGR) reflecting the rate of biomass gain over time, was calculated using the formula: $\text{CGR (g m}^{-2}\text{ day}^{-1}\text{)} = \frac{w_2 - w_1}{t_2 - t_1}$. Where, W₂ and W₁ are the final and initial dry weight of the crop at the time t₂ and t₁ respectively.

Yield attributes were measured at maturity stage, the number of ear head-bearing tillers was counted from four random area of 0.25 m² areas within the net plot, and that process was repeated during the crop's growth period to record tiller numbers. The length of the ear heads, excluding the awns, was studied from five tagged plants in each plot, and the average length was calculated in centimeters. To determine the grains per ear head, five ear heads from each plot were manually

threshed, and the grains were counted to obtain an average number. Finally, after threshing and winnowing, a representative grain sample was taken from each plot, and 1,000 grains were randomly selected using a mechanical seed counter. Their total weight was then recorded in grams as test weight.

Yield of wheat crop was measured after harvesting and cleaning from each plot separately. The yield (grain) was calculated at 12% moisture content likewise for measuring straw yield, straw samples were dried to a constant weight and the dry weight data were then converted to kg ha⁻¹. Harvest index was derived by using the formula

$$H. I. = \frac{\text{Economic yield (grain yield) Kg ha}^{-1}}{\text{Biological yield (grain + straw)}} \times 100 ; \text{ expressed as percentage (\%)}$$

To measure the nutrient uptake, plant samples from each treatment were collected and oven dried at 60 ± 5 °C for 48 hours. Followed by grinding and sieving through a 30 mesh sieves. Estimation of the nitrogen content in wheat plant samples was done through modified Kjeldahl's method (Jackson, 1967). The tri-acid digested plant samples were used for estimating phosphorus content by vanadomolybdo phosphoric acid yellow colour method (Jackson, 1973). Potassium content of the extractant of tri-acid digested material was estimated using flame photometer.

3. RESULT AND DISCUSSION

3.1 EFFECTS OF NANO UREA ON GROWTH PARAMETERS OF WHEAT

The application of varying nitrogen levels combined with foliar sprays of nano urea and water, significantly influenced wheat crop growth parameters. The foliar spray of nano urea enhanced plant height, number of tillers, leaf area index (LAI) and dry matter accumulation throughout all growth stages. This improvement is attributed to the consistent availability of nitrogen during critical growth phases, such as tillering and jointing. The increased nutrient supply from nano urea supports various metabolic processes, enhancing physiological and biochemical functions that promote apical growth and expanded photosynthetic areas resulting from meristematic activities. The foliar application of nano nitrogen, which penetrates easily through stomata, increased nutrient uptake, boosting carbohydrate mobilization into amino acids and proteins, thereby stimulating rapid cell division and elongation. These findings align with studies by Sharma et al. (2022), Rajasekar et al. (2015), AL-Gym AJK and Al-Asady MHS (2020), and Chandana (2021).

Table 1: Effect of nano urea on plant height, tiller count, leaf area index (LAI) and Crop growth rate (CGR) at the time of maturity.

Treatments		Plant height (cm)	No. of tillers m ⁻²	LAI	CGR
T ₁	RDN + water spray	92.80	298.67	3.28	0.99
T ₂	RDN + one spray of nano urea	93.27	302.69	3.41	1.13
T ₃	RDN + two spray of nano urea	94.64	305.59	3.83	1.03
T ₄	RDN + two spray of urea (5%)	95.38	318.52	3.87	1.24
T ₅	75 % RDN + water spray	85.12	288.85	2.71	1.86
T ₆	75 % RDN + one spray of nano urea	87.23	279.15	2.85	2.06

T ₇	75 % RDN + two spray of nano urea	88.92	282.90	3.00	3.25
T ₈	75 % RDN + two spray of urea (5 %)	89.23	295.58	3.15	2.59
T ₉	50 % RDN + water spray	80.97	220.71	2.37	2.10
T ₁₀	50 % RDN + one spray of nano urea	81.58	232.38	2.44	2.33
T ₁₁	50 % RDN + two spray of nano urea	82.77	253.64	2.50	2.15
T ₁₂	50 % RDN + two spray of urea (5 %)	83.32	268.27	2.60	4.94
T ₁₃	Control	76.68	185.59	1.99	4.12
SEm (±)		2.93	12.21	0.24	1.14
CD at 5 %		8.55	35.63	0.71	NS

The nitrogen levels significantly affected tiller density (tillers per square meter) across all growth stages, with a sharp increase observed between 25 and 75 days after sowing (DAS), followed by a decline towards maturity. Notably, the highest tiller density was recorded in treatments receiving recommended nitrogen doses (RDN) and two foliar sprays of nano urea during tillering and jointing stages, closely followed by treatments with RDN + two sprays of 5% urea. This sustained nutrient release from nano fertilizers positively impacted plant growth by maintaining a consistent nutrient supply, further confirmed by the increased nitrogen uptake and enhanced cell activities noted in similar studies.

Nitrogen’s role in promoting cell division-elongation and tissue differentiation contributes to vegetative growth by increasing plant height and leaf size. A larger leaf area improves sunlight interception, leading to more assimilate production, thereby enhancing overall crop growth and development. These findings are consistent with the result of Bhanuchandar et al. (2020), Choudhary et al. (2020), Mandeewal et al. (2020), and Rahman et al. (2014), who reported that increase in dry matter accumulation was due to higher photosynthetic rates and larger leaf areas.

Table 2: Effect of nano urea on dry matter accumulation of wheat.

Treatments		Dry matter accumulation (g m ⁻²)				
		25 DAS	50 DAS	75 DAS	100 DAS	At maturity
T ₁	RDN + water spray	83.66	237.85	375.38	532.01	556.82
T ₂	RDN + one spray of nano urea	81.34	243.31	380.61	533.33	561.67
T ₃	RDN + two spray of nano urea	83.55	245.09	387.19	540.96	566.77
T ₄	RDN + two spray of urea (5%)	79.49	249.01	393.72	555.52	571.19
T ₅	75 % RDN + water spray	78.18	223.64	362.30	481.96	528.45
T ₆	75 % RDN + one spray of nano urea	78.75	230.91	364.89	487.30	538.71
T ₇	75 % RDN + two spray of nano urea	81.88	232.86	370.41	459.10	540.33
T ₈	75 % RDN + two spray of urea (5 %)	81.14	242.12	373.63	497.08	561.78
T ₉	50 % RDN + water spray	76.69	190.74	340.38	415.63	468.15
T ₁₀	50 % RDN + one spray of nano urea	78.09	200.04	352.24	425.45	483.76

T ₁₁	50 % RDN + two spray of nano urea	77.92	208.30	357.17	436.96	490.77
T ₁₂	50 % RDN + two spray of urea (5 %)	80.09	215.41	358.82	371.93	495.55
T ₁₃	Control	80.22	179.35	292.17	318.77	421.89
SEm (±)		4.35	9.59	17.01	22.44	22.06
CD at 5 %		NS	28.00	49.64	65.49	64.38

**Two spray: 1st at tillering and 2nd at jointing stage

**One spray: tillering stage

3.2 Effect of nano urea on yield attributes and yield.

The economic yield of wheat is influenced by various components, including the number of ear heads meter⁻², ear head length, grains per ear head, and 1000-grain weight. These yield attributes are developed during the vegetative phase, where healthy vegetative growth enables optimal expression of these characteristics. The yield of a crop reflects the aggregate effect of these attributes, which are influenced by both environmental conditions and genetic traits.

Experimental results indicate that increasing nitrogen levels and applying a 4% foliar spray of nano urea significantly enhance yield attributes such as ear head number and length, grains per ear head, and test weight. This improvement is likely due to the continuous nitrogen supply provided by nano urea at critical growth stages, promoting meristematic activity. Similar result was observed by Jassim et al. (2019). The elongation of ear heads may be attributed to nano urea's ability to enhance water and nutrient absorption, thereby improving photosynthesis. Additionally, nano-NPK acts as a biological pump, facilitating nutrient and water uptake, as reported by Wu M (2013) and Ma et al. (2010). The increase in grains per ear head is likely due to the enhanced rate of assimilation followed by translocation of photosynthates from the leaves to grains, supported by timely nitrogen supply through foliar spray. This observation aligns with the findings of AL-gym AJK and Al-Asady MHS (2020). Test weight improvement is also linked to better water and nutrient absorption facilitated by nano-NPK, leading to enhanced photosynthesis, as observed by Wu (2013).

Table 3: Effect of nano urea on yield attributes of wheat

Treatments		Ear head m ⁻²	Grains ear head ⁻¹	1000- grain weight (g)	Spike length (cm)
T ₁	RDN + water spray	276.22	48.00	42.40	9.77
T ₂	RDN + one spray of nano urea	279.18	48.67	43.16	10.16
T ₃	RDN + two spray of nano urea	282.89	50.00	43.48	10.40
T ₄	RDN + two spray of urea (5%)	286.05	51.67	43.97	10.83
T ₅	75 % RDN + water spray	269.79	43.00	41.75	8.93
T ₆	75 % RDN + one spray of nano urea	272.79	47.00	42.22	9.00
T ₇	75 % RDN + two spray of nano urea	273.63	47.67	42.83	9.34

T ₈	75 % RDN + two spray of urea (5 %)	286.73	48.33	42.98	9.40
T ₉	50 % RDN + water spray	252.53	46.00	39.68	6.50
T ₁₀	50 % RDN + one spray of nano urea	253.16	46.67	40.22	7.00
T ₁₁	50 % RDN + two spray of nano urea	253.96	46.00	41.12	7.43
T ₁₂	50 % RDN + two spray of urea (5 %)	255.97	46.33	41.71	7.67
T ₁₃	Control	200.38	43.67	34.63	6.00
SEm (±)		14.72	2.22	1.80	0.50
CD at 5 %		42.97	6.48	5.24	1.45

**Two spray: 1st at tillering and 2nd at jointing stage

**One spray: tillering stage

The final yield of wheat, encompassing both grain and straw yield, varies significantly based on location. It is determined by the genotype's potential, the environmental conditions throughout the plant's life cycle, and agronomic management practices. Data shows that highest grain yield of 4492 kg ha⁻¹ was recorded in treatment T₃, where two nano urea sprays at tillering and jointing stages, along with 100% RDN, were applied. This yield was statistically similar to the highest yield of 4573 kg ha⁻¹ obtained in treatment T₄, which involved two sprays of a 5% urea solution at the same stages along with 100% RDN. The combination of nano fertilizers with traditional nitrogen fertilizers enhances nutrient absorption efficiency, photosynthesis, and nutrient translocation, ultimately boosting economic and biological yields. The observed increase in yield parameters due to nano urea spray aligns with the results of Kumar et al. (2020), Khalil et al. (2019), Ma et al. (2010), and Liu and Liao (2008).

Table 4: Effect of nano urea on grain yield, straw yield, biological yield and harvest index of wheat.

	Treatments	Grain yield (kg ha ⁻¹)	Straw yield (kg ha ⁻¹)	Biological yield (kg ha ⁻¹)	Harvest Index (%)
T ₁	RDN + water spray	4210.00	5078.20	9288.20	45.29
T ₂	RDN + one spray of nano urea	4423.33	5098.32	9521.65	46.40
T ₃	RDN + two spray of nano urea	4492.33	5235.67	9728.00	46.08
T ₄	RDN + two spray of urea (5%)	4573.33	5319.33	9892.67	46.25
T ₅	75 % RDN + water spray	3927.33	5033.33	8960.67	43.72
T ₆	75 % RDN + one spray of nano urea	4030.00	5142.97	9172.97	43.98
T ₇	75 % RDN + two spray of nano urea	4116.67	5174.97	9291.64	44.29
T ₈	75 % RDN + two spray of urea (5 %)	4240.33	5230.68	9471.01	44.66
T ₉	50 % RDN + water spray	3254.67	4244.80	7499.46	43.47
T ₁₀	50 % RDN + one spray of nano urea	3391.67	4494.17	7885.84	43.30
T ₁₁	50 % RDN + two spray of nano urea	3444.33	4533.33	7977.67	43.10
T ₁₂	50 % RDN + two spray of urea (5 %)	3469.00	4606.67	8075.67	42.98

T ₁₃	Control	2938.33	3809.00	6747.33	43.87
SEm (±)		148.43	194.87	268.96	1.63
CD at 5 %		433.23	568.79	785.05	NS

**Two spray: 1st at tillering and 2nd at jointing stage

**One spray: tillering stage

3.3 Effect of Nano urea on nitrogen use efficiency (NUE)

Nano urea, a nanotechnology-based urea formulation, enhances nutrient use efficiency in crops by releasing nitrogen more slowly than traditional urea. This controlled release ensures a steady nutrient supply throughout the crop's growth period, improving overall nitrogen availability, especially when applied as a foliar spray. Due to their smaller size, nano urea particles are more easily absorbed through leaf pores, leading to better nutrient accumulation in plant vacuoles, which are released as needed. This synchronization of nitrogen availability with the crop's nitrogen demand significantly boosts nitrogen use efficiency (NUE). Research by Liscano et al. (2000) supports these findings, emphasizing that the timing of nitrogen application is crucial for maximizing crop uptake and minimizing losses. In one study, the highest NUE (10.2 kg ha⁻¹) was observed in a treatment combining 75% of the recommended nitrogen dose with two foliar sprays of 4% nano urea at tillering and jointing stages.

Table 5: Total Nutrient uptake and Nitrogen use efficiency as affected by nano urea.

Treatments	Nutrient Uptake				Nitrogen Use Efficiency (Kg Kg ⁻¹)	
	N	P	K	Total (NPK)		
T ₁ RDN + water spray	104.60	17.28	68.01	63.30	8.50	
T ₂ RDN + one spray of nano urea	117.85	18.22	69.45	68.51	9.80	
T ₃ RDN + two spray of nano urea	121.28	18.50	70.30	70.03	10.10	
T ₄ RDN + two spray of urea (5%)	123.30	18.89	72.41	71.53	9.70	
T ₅ 75 % RDN + water spray	97.31	16.29	65.83	59.81	8.80	
T ₆ 75 % RDN + one spray of nano urea	109.52	16.53	67.87	64.64	9.60	
T ₇ 75 % RDN + two spray of nano urea	111.43	17.06	69.03	65.84	10.20	
T ₈ 75 % RDN + two spray of urea (5 %)	113.59	17.70	69.95	67.08	9.90	
T ₉ 50 % RDN + water spray	79.83	13.26	54.41	49.17	4.20	
T ₁₀ 50 % RDN + one spray of nano urea	86.08	14.07	58.20	52.78	5.90	
T ₁₁ 50 % RDN + two spray of nano urea	87.40	14.24	59.05	53.56	6.50	
T ₁₂ 50 % RDN + two spray of urea (5 %)	88.37	14.82	60.01	54.40	5.70	
T ₁₃ Control	67.45	11.60	49.42	42.82	-	
SEm (±)		3.11	3.11	2.15	4.56	1.32

CD at 5 %	9.07	9.07	6.28	13.30	3.9
-----------	------	------	------	-------	-----

REFERENCE

AL-Gym AJK, Al-Asady MHS. Effect of the method and level of adding NPK nanoparticles and mineral fertilizers on the growth and yield of yellow corn and the content of mineral nutrient of some plant parts. *Plant Archives*. 2020;20(1):38-43.

Bhanuchandar B, Prasanthi M, Dawson J. Effect of levels of nitrogen and potassium on growth and yield of rainfed pearl millet (*Pennisetum glaucum* L.). *Int J Curr Microbiol Appl Sci*. 2020;9:2194-7.

Chandana P, Latha KR, Chinnamuthu CR, Malarvizhi P, Lakshmanan A. Efficiency of foliar applied nano-nutrients (nitrogen, zinc, and copper) on growth and yield of rice at harvest. *Biol Forum*. 2021;1104-8.

Choudhary V, Sharma PK, Mandeewal RL, Verma BL, Choudhary R. Effect of nitrogen and phosphorus on growth, yield, and quality of coriander (*Coriandrum sativum* L.). *Ann Agric Res (New Series)*. 2020;41:322-4.

Khalil MH, Abou-Hadid AF, Abdrabou RT, Al-halim A, AbdEl-Maaboud MS. Response of two maize cultivars (*Zea mays* L.) to organic manure and mineral nano nitrogen fertilizer under Siwa Oasis conditions. *Arab Univ J Agric Sci*. 2019;27(1):299-312.

Kumar Y, Tiwari KN, Nayak RK, Rai A, Singh SP, Singh AN, Raliya R. Nanofertilizers for increasing nutrient use efficiency, yield, and economic returns in important winter season crops of Uttar Pradesh. *Indian J Fert*. 2020;16(8):772-86.

Liscano JF, Wilson CE, Norman RJ, Slaton NA. Zinc availability to rice from seven granular fertilizers. Fayetteville (CA): Arkansas Agricultural Experiment Station; 2000. Vol. 963.

Liu AX, Liao ZW. Effects of nano-materials on water clusters. *J Anhui Agric Sci*. 2008;36:15780-1.

Ma Y, Kuang L, He X, Bai W, Ding Y, Zhang Z, et al. Effects of rare earth oxide nanoparticles on root elongation of plants. *Chemosphere*. 2010;78(3):273-9.

Mandeewal RL, Soni ML, Gulati IJ, Shivran H, Choudhary R. Effect of irrigation and nitrogen levels on clusterbean (*Cymopsis tetragonoloba*) in IGNP Stage-II. (Note: Journal name and details are missing.)

Rahman MZ, Islam MR, Karim MA, Islam MT. Response of wheat to foliar application of urea fertilizer. *J Sylhet Agril Univ*. 2014;1(1):39-43.

Rajasekar M, Nandhini DU, Suganthi S. Supplementation of mineral nutrients through foliar spray-A review. *Int J Curr Microbiol Appl Sci*. 2015;6(3):2504-13.

Sharma SK, Sharma PK, Mandeewal RL, Sharma V, Chaudhary R, Pandey R, et al. Effect of foliar application of nano-urea under different nitrogen levels on growth and nutrient content of pearl millet (*Pennisetum glaucum* L.). *Int J Plant Soil Sci*. 2022;34(20):149-55.

Wu M. Effects of incorporation of nano-carbon into slow-released fertilizer on rice yield and nitrogen loss in surface water of paddy soil. *Adv J Food Sci Technol*. 2013;5:398-403.