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EVALUATION OF NANO AND PRILLED UREA FOR YIELD ENHANCEMENT OF WHEAT UNDER RESTRICTED IRRIGATED CONDITIONS

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ABSTRACT

The field experiment was conducted during 2021-22 and 2022-23 at CCS Haryana Agricultural University, Hisar, India, to evaluate the efficacy of foliar application of nano and conventional prilled urea on wheat crop (WH 1270) under restricted irrigation conditions. Under restricted irrigation, optimization of nitrogen management using different doses and sources is essential to maximise crop productivity and better resource use efficiency while mitigating environmental losses. The experiment was conducted in a randomised block design with nine treatments under varying nitrogen application regimes. The treatments involved the spraying of nano urea at tillering and jointing stage along with the recommended dose of nitrogen. The results revealed that supplementing the recommended dose of nitrogen (RDN *i.e.*; 150 kg ha^{-1}) with two foliar sprays of nano urea at the tillering and jointing stages recorded significantly higher grain (44.54 q ha^{-1} and 54.05 q ha^{-1}) and biological yield (117 q ha^{-1} and 149 q ha^{-1}) during 2021-22 and in 2022-23, respectively. However, the grain and biological yield were statistically at par with RDN supplemented by two sprays of conventional urea @ 5% or a combined spray of urea @5% and nano urea. The integration of two foliar nano urea sprays with RDN achieved a 6.5% yield enhancement over the control (RDN alone). Overall, integrating a foliar spray of nano urea with conventional urea is viable agronomic strategy to enhance nutrient assimilation, crop growth and grain yield in restricted-irrigation wheat systems.

Key words : Nano urea, Restricted irrigation, Nitrogen and Grain yield.

Introduction

Wheat is one of the most important cereal crops worldwide, contributing to food security and hunger strike. Globally, 799.1 million metric tons of wheat were produced from an area of 224.5 million hectares (USDA, 2025). In India, wheat ranks as the second most important cereal, with an area of more than 33.60 million hectares producing 120.65 million tons (DES, 2026). In India, the productivity of wheat is 3,610 kg ha^{-1}, which is 39.5% less than that of China with a productivity of 5,970 kg ha^{-1} (USDA, 2026). The reduction is mainly due to small-scale farming practices, slower pace of adoption of improved technologies, high-yield varieties and other agronomic practices. The challenges in wheat cultivation further arise due to climate change and water scarcity. India, having a key position among the major wheat-producing countries, faces these challenges while striving to sustain adequate wheat yields for its growing population. During the growing cycle, wheat generally requires 400 to 700 mm of water, depending upon variations in temperature, humidity and soil conditions (Singh *et al*., 2025; Sarto *et al*., 2017 and Vashisht *et al*., 2019). In areas with less and erratic rainfall, restricted irrigation practices are gaining recognition to obtain high water use efficiency (Meena *et al*., 2019). Limited irrigation practices target the critical growth stages to enhance water productivity, minimise resource waste and promote sustainable agriculture amidst growing competition for diminishing water resources. Concurrently, inefficient nitrogen management aggravated by soil degradation and low fertiliser uptake leads to diminished crop response, rising input costs and escalating environmental degradation.

Generally, the nitrogen use efficiency of urea ranges from 20% to 50%, which declines with increasing application rates due to leaching and volatilisation losses (Sood *et al*., 2025). In regions with extremely low irrigation levels or those that are rainfed, farmers usually apply the complete dose of nitrogen at the beginning of the growing season, which leads to stagnation in wheat productivity of wheat owing to the lack of synergism between irrigation and application of nitrogen. In addition, there is an enormous environmental concern with continuous reliance on mineral fertilisers, based on estimates that nitrogen losses from leaching can be as high as 46% to 66%, posing challenges to ecosystems and water resources (Kumar *et al*., 2025; Peng *et al*., 2015). Therefore, foliar application of nano fertilisers may be a good alternative to soil-applied fertilisers to obtain better fertiliser use efficiency. Foliar fertiliser application enables the uptake of nutrients directly into the leaves, thus greatly improving nutrient-use efficiency over normal soil applications (Wu *et al*., 2025; Singh *et al*., 2025). In area of limited irrigation, application of urea via foliar spray at the critical growth stages would ensure availability of nitrogen during critical growth phases (Mousavi *et al*., 2025). Nano-fertilisers are 1-100 nm in particle size and may become the next generation fertilisers for better nutrient-use efficiency due to their unique characteristics (Kumar *et al*., 2023). Nano urea-based fertilisers with 4% nitrogen can substitute conventional urea more efficiently for higher use efficiency of nitrogen (Dhabi *et al*., 2026; Sood *et al*., 2025). While nano urea has the potential to replace conventional granular urea to reduce excessive nitrogen reliance, precise dose optimisation is essential to prevent adverse impacts on crop growth and yield. Consequently, evaluating application strategies for nano urea under restricted irrigation across India's diverse agro-climatic zones is vital for maximising productivity and water-use efficiency for wheat crop (Rani *et al*., 2024).

Materials and Methods

Experimental-site

The field experiment was conducted during the *Rabi* season of 2021-22 and 2022-23 at Wheat and Barley Section Research Area, CCS Haryana Agricultural University, Hisar (Haryana) situated at 29°1′N latitude and 75°46′E longitude with a height of 215.2 meters above mean sea level. The soil of experimental field was low in available nitrogen (142.8 kg ha^{-1}), medium in available phosphorus (12.3 kg ha^{-1}) and high in available potassium (248.4 kg ha^{-1}) with 0.45% organic carbon. It was moderately alkaline with a of pH 7.8 and an electrical conductivity of 0.28 dS m^{-1}.

Treatment details

The experiment was conducted in randomised block design (RBD) with 9 treatments: [T_1- One spray of nano urea at tillering stage (40-45 DAS), T_2- Two spray of nano urea at tillering (40-45 DAS) and jointing stage (60-65 DAS), T_3- Recommended dose of nitrogen (RDN), T_4- RDN + one spray of nano urea at tillering, T_5- RDN + two spray of nano urea at tillering and jointing, T_6- RDN +one spray of urea (5%) at tillering, T_7- RDN + two spray of urea (5%) at tillering and jointing, T_8- RDN + one spray of urea (5%) + nano urea at tillering, T_9- Absolute control (No nitrogen)] and each treatment was replicated thrice. Wheat variety WH 1270 was sown with a seed rate of 100 kg ha^{-1}on 11th November and 12th November during 2021 and 2022, respectively. Nitrogen fertiliser was applied in two splits according to treatment specifications: ½ as a basal dose, and the remaining ½ dose of nitrogen at the first irrigation (CRI stage). Recommended doses of phosphorus and potassium were applied uniformly as basal at the sowing across all treatments. Foliar nano urea was applied at a concentration of 4 mL L^{-1} of water, using a spray volume of 400 L ha^{-1}.

Observations recorded

Physiological parameters like leaf chlorophyll content were evaluated using a SPAD meter and canopy temperature was measured with an infrared thermometer. Other management practices were adopted as per recommendations for wheat crop for restricted irrigation conditions. Data on plant height, number of effective tillers, number of grains $earhead^{-1}$, 1000-grain weight, grain yield and straw yield were recorded using a standard procedure. Data were analysed statistically using OPSTAT software.

Results and Discussion

Plant height

The data presented in Table 1, revealed that plant height showed a significant variation among different treatments. The treatment having RDN + two sprays of urea (5%) at tillering and jointing recorded significantly higher plant height (99.85 and 104.00 cm) than other treatments during 2021-22 and 2022-23, respectively) and was statistically at par with T_4, T_5, T_6 and T_8. The higher plant height in this treatment may be attributed to increased nitrogen availability and higher root uptake which facilitated higher protoplasm synthesis and accelerated cell division and elongation, which collectively drove vital vegetative growth (Sisodiya *et al*., 2024 and Jadhav *et al*., 2023).

Table 1 : Effect of nano urea on plant height and yield attributes of wheat.

Treatments	Plant height (cm)		Effective tillers/m²		Grains/Earhead		1000-grains weight (g)	
	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23
T_1	88.29	92.00	332	340	32.68	46.70	32.25	33.92
T_2	90.60	94.10	340	347	33.42	47.40	32.68	33.93
T_3	96.90	101.53	403	391	29.96	51.20	35.06	33.07
T_4	96.90	102.00	408	395	30.07	51.73	35.25	33.02
T_5	99.70	103.67	412	410	30.43	55.80	35.53	34.23
T_6	97.20	101.80	405	391	30.52	54.23	34.98	33.07
T_7	99.85	104.00	413	406	30.37	55.70	35.40	34.18
T_8	98.78	103.00	408	411	30.78	54.87	35.46	33.59
T_9	83.40	86.33	283	330	31.14	43.03	31.88	35.42
LSD (p=0.05)	**4.01**	**5.15**	**53**	**37**	**NS**	**2.69**	**2.26**	**1.31**

Effective tillers m^{-2}

The perusal of the data given in the Table 1, showed that different treatments had a significant effect on the numbers of effective tillers m^{-2}, which were significantly higher in treatment RDN + two spray of urea (5%) at tillering and jointing (413) in 2021-22 but during 2022-23 RDN + one spray of urea (5%) + nano urea at tillering recorded significantly higher tillers/m^2 (411) than other treatments, which was statistically at par with T_3, T_4, T_5, T_6 and T_8 treatments during both the years. The increase in effective tillers/m^2 might be due to enhanced nitrogen uptake and the sustained nutrient-release capacity of nano-fertilisers, which ensures a steady supply of nutrients to promote plant growth. Foliar application of nano urea facilitated efficient nitrogen absorption through both foliar and root pathways. This elevated nitrogen status accelerated the metabolic conversion of carbohydrates into amino acids and proteins, thereby stimulating cell division and elongation. These results are similar with the findings of Rani *et al*. (2024) and Sarkar *et al*. (2023) have reported similar findings.

Grains earhead^{-1}

The results presented in Table 1 reported that grains/earhead did not show any significant difference during the year 2021-22 but were recorded higher with treatment two spray of nano urea at tillering (40-45 DAS) and jointing stage (60-65 DAS) (33.42). However, a significant variation among different treatments regarding grains earhead^{-1} was found during 2022-23. Maximum grains earhead^{-1} (55.70) were recorded with T_7 among the treatments, which was statistically at par with T_5, T_6 and T_8. Foliar nitrogen application enhances chlorophyll synthesis, leaf area index and photosynthetic efficiency. The resulting increase in photo-assimilates and optimised carbohydrate partitioning to the developing earhead significantly boosts grains earhead^{-1} (Kumar *et al*., 2021).

1000 grains weight

1000 grains weight was recorded significantly higher with the treatment RDN + two spray of nano urea at tillering and jointing (35.53) and control (35.42) as compared to other treatments but was statistically at par with treatments T_3, T_4, T_6, T_7 and T_8 during 2021-22 and with T_7 in 2022-23, respectively. Applying nitrogen increases tiller survival, resulting in more effective panicles per unit area and higher grain counts per earhead (Zhang, 2024).

Grain yield

Data presented in Table 2 indicated that nitrogen treatments had a significant effect on grain yield, the highest grain yield was recorded (44.54 and 54.05 q/ha during 2021-22and 2022-23, respectively) with treatment RDN + two spray of nano urea at tillering and jointing which was significantly higher than other treatments, but statistically at par with treatments T_3 (42.27 q ha^{-1}), T_4 (43.22 q ha^{-1}), T_6 (43.03 q ha^{-1}), T_7 (44.35 q ha^{-1}) and T_8 (44.12 q ha^{-1}) during 2021-22 and T_4 (50.97 q ha^{-1}), T_6 (51.70 q ha^{-1}), T_7 (53.74 q ha^{-1}) and T_8 (53.23 q ha^{-1}) during 2022-23, respectively. These results may be attributed to the synergistic effect of combining soil-applied urea with foliar spray of nano-fertilisers, which enhanced nutrient absorption efficiency, translocation and photosynthetic rates, ultimately boosting economic and biological yields. The concurrent improvements in vegetative growth dynamics and yield attributes by foliar nano-urea application directly contributed to higher total grain production. These results are similar to the findings of Rani *et al*. (2024a), Sisodiya *et al*. (2024), Ojha *et al*. (2023), Sarkar *et al*. (20230, Al-Shamary and Ansari (2022), Rahman *et al*. (2019) and Al-Juthery *et al*. (2018).

Biological yield

The maximum biological yield (112 and 149 q/ha

Table 2 : Effect of nano urea on grain yield, biological yield and harvest index of wheat.

Treatments	Grain yield (q/ha)		Biological yield (q/ha)		Harvest Index (%)	
	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23
T_1	34.84	34.62	101	98.6	34.5	35.1
T_2	36.96	37.48	105	106.5	35.2	35.2
T_3	42.27	49.25	112	137.1	37.7	35.9
T_4	43.22	50.97	114	141.2	37.9	36.1
T_5	44.54	54.05	117	149.0	38.1	36.3
T_6	43.03	51.70	114	143.2	37.7	36.1
T_7	44.35	53.74	117	148.3	37.9	36.2
T_8	44.12	53.23	116	146.9	38.0	36.2
T_9	27.84	32.51	83	92.9	33.5	35.0
LSD (p=0.05)	**4.65**	**3.91**	**12**	**10.3**	**NS**	**NS**

Table 3 : Effect of nano urea on physiological parameters.

Treatment	Canopy temperature (°C) at 15 DAA		NDVI at 15 DAA	
	2021-22	2022-23	2021-22	2022-23
T_1	28.7	28.7	0.73	0.71
T_2	26.2	26.2	0.74	0.74
T_3	24.8	25.3	0.75	0.75
T_4	25.7	25.7	0.73	0.71
T_5	26.1	26.1	0.76	0.78
T_6	28.7	28.7	0.74	0.74
T_7	28.8	28.8	0.73	0.73
T_8	26.5	26.5	0.74	0.77
T_9	30.5	30.2	0.72	0.70
Range	24.8 – 30.5	25.3 - 30.2	0.72 - 0.76	0.70 - 0.78

during 2021-22 and 2022-23, respectively) was observed with treatment RDN + two spray of nano urea at tillering and jointing, which was significantly higher than treatments T_1 and T_9 during 2021-22 and T_1, T_2, T_3 and T_9 during 2022-23 (Table 2). Nitrogen is a critical structural and functional component of plant tissues that drives cell division and elongation, thereby exerting a synergistic influence on vegetative growth parameters such as plant height, leaf count and dry matter accumulation (Srivani *et al.*, 2022). Furthermore, an adequate supply of nitrogen enhances meristematic activity and leaf canopy expansion, facilitating greater photosynthetic capacity and assimilate production, which ultimately translates into higher biomass production. These results are in conformity with Sisodiya *et al*. (2024), Samui *et al*. (2022), Sarkar *et al*. (2023), Ojha *et al*. (2023) and Al-Juthery *et al*. (2018).

Canopy temperature (°C)

The data presented in the Table 3, showed that the canopy temperature at 15 DAA ranged from (24.8-30.5°C and 25.3-30.2°C), which was found highest in treatment control (30.5 and 30.2°C) and lowest in recommended dose of nitrogen (24.8 and 25.3°C) during 2021-22 and 2022-23, respectively. Nitrogen plays a key role in controlling guard cells and regulating stomata. Applying nano urea or conventional urea directly to leaves at the tillering and jointing stages boosts leaf nitrogen levels, chlorophyll content, and stomatal opening. Higher stomatal conductance speeds up transpiration, driving a cooling effect that keeps the crop canopy significantly cooler than the surrounding air. These results are confirm with (Mousavi *et al*., 2025 and Li *et al*., 2024).

NDVI

The perusal of the data presented in the Table 3 showed that NDVI at 15 DAA of different treatments ranged from (0.72-0.76 and 0.70-0.78), which was found highest in treatment RDN + two spray of nano urea at tillering and jointing (0.76 and 0.78) whereas, the lowest was recorded in control (0.72 and 0.70) during 2021-22 and 2022-23, respectively. Supplemental foliar nitrogen applied at critical vegetative stages, specifically tillering and jointing enhances leaf nitrogen levels and prevents premature chlorophyll degradation in flag leaves (Dabhi *et al*., 2026 and Singh *et al*., 2025a).

Conclusion

Based on a two-year study under restricted irrigation conditions in wheat, two sprays of nano urea or prilled urea at the tillering and jointing stage or one spray of prilled urea (5%) + nano urea at tillering, along with the recommended dose of nitrogen (150 kg ha^{-1}) significantly improved grain yield of wheat as compared to RDN application alone. Application of two sprays of nano urea at the tillering and jointing stage brought an increase of 9.75% in grain yield over RDN alone.

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