Biological Forum
an International Journal 17(5): 22-26(2025)
ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Impact of Integrated Nano and Non-nano Urea on Nitrogen Efficiency and Uptake in Grain and Straw in Late Sown Wheat

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(Received: 13 February 2025; Revised: 22 March 2025; Accepted: 14 April 2025; Published online: 07 May 2025)
(Published by Research Trend)

ABSTRACT: The present study entitled, "Impact of Integrated Nano and Non-nano urea on Nitrogen Efficiency and uptake in grain and straw in late sown wheat" was conducted at Samargopalpur farm of CCSHAU Regional Research station, Rohtak during the Rabi season of 2022-23 and 2023-24 The experiment was laid out in randomized block design with eight different treatment combination of integrated use of nano and non-nano urea on late sown wheat (DAS) replicated thrice. Based on the research investigation it was found that application of nano and non-nano urea. Results revealed that the treatment involving 50% recommended dose of nitrogen (RDN) through urea + 2 sprays of nano urea (T_6) exhibited superior NUE indices like agronomic efficiency and partial factor productivity. This implies that nano urea can integrated with conventional urea for improving nutrient uptake.

Keywords: Wheat, Urea, Nano Urea, late sown, foliar spray, RDN.

INTRODUCTION

Wheat (*Triticum aestivum* L.) stands as a critical staple food crop globally, playing a vital role in ensuring food security. Wheat is cultivated across 34.8 million hectares, yielding a total production of 113 million tonnes and a productivity rate of 3217 kg per hectare (kg ha^{-1}) in India (Anonymous, 2023). Haryana contributes 9.8% of total wheat production in India and grown on 2.52 million hectares, achieving yields of 1.1 million tonnes and a productivity of 4365 kg ha^{-1} (Anonymous, 2024). By 2050, wheat demand is expected to increase by 31% compared to the 683 million tonnes recorded in 2008 (Ramadas *et al.*, 2019). In India and various other regions, the late sowing of wheat is frequently necessitated by agronomic and climatic challenges, particularly within rice–wheat cropping systems. Such delayed sowing subjects the crop to terminal heat stress, which adversely affects grain yield, quality, and nutrient use efficiency. Among the numerous agronomic strategies available, the implementation of balanced and effective nitrogen management is essential for alleviating the negative impacts of late sowing and improving crop performance.

While conventional urea is a commonly utilized nitrogen fertilizer, it is characterized by low nitrogen use efficiency (NUE), resulting in significant nitrogen losses through processes such as volatilization, leaching, and denitrification. These losses not only diminish crop productivity but also contribute to environmental degradation. Recently, nano urea—a novel formulation of nitrogen at the nano-scale—has emerged as a viable alternative, noted for its high reactivity, targeted delivery, and minimized nutrient losses. In contrast to bulk urea, nano urea is absorbed more effectively by plant foliage and has the potential to either supplement or partially replace traditional nitrogen sources. The application of foliar fertilization using either nano or conventional fertilizers, particularly nano urea, has the potential to mitigate the issues related to the excessive use of bulk urea (Rathnayaka *et al.*, 2018).

The combined application of nano and non-nano urea presents a synergistic strategy that capitalizes on the rapid absorption of nano urea while ensuring the sustained availability offered by conventional urea. This integrated approach may enhance NUE, improve grain quality indicators such as protein content and test weight, and promote superior crop performance under the stress conditions associated with late sowing. Nevertheless, research exploring the joint application of nano and non-nano urea in late sown wheat scenarios remains scarce and requires thorough investigation. Nano Urea, with a particle size ranging from 20 to 50 nm, has emerged as a groundbreaking and environmentally sustainable alternative. It provides improved nutrient utilization efficiency and lowers cultivation expenses, as a 500 ml bottle of 4% (w/v) is equivalent to a 45 kg bag of urea (Frank and Husted 2024; Kumar *et al.,* 2023). Additionally, it enhances both crop yield and quality by facilitating absorption through stomata and other leaf openings.

Consequently, this study seeks to assess the impact of the integrated application of nano and non-nano urea on the yield, quality characteristics, and nitrogen use efficiency of late sown wheat, thereby providing valuable insights into optimizing nitrogen management for sustainable wheat production.

MATERIALS AND METHODS

The field experiment was conducted during the *Rabi* seasons of 2022–23 and 2023–24 at the research farm of CCS Haryana Agricultural University, Regional Research Station, Rohtak (Haryana, India). The experiment, conducted in an RBD with eight treatments and three replications, used WH 1124 wheat variety suited for late sowing.

The soil of the experimental field was sandy loam in texture, slightly alkaline in reaction (pH 8.1), and low in available nitrogen (120 kg ha^{-1}), medium in available phosphorus (36 kg ha^{-1}), and medium in available potassium (165 kg ha^{-1}). The organic carbon content was found to be 0.61%. Detailed analytical methods and initial soil properties are presented in Table 1.

Table 1: Initial physiochemical chemical properties of soil.

Components		Initial values	Methods used
A.	**Mechanical analysis**		
	Sand (%)	35.1	International Pipette Method (Piper,1966)
	Silt (%)	29.7	
	Clay (%)	35.00	
B.	**Chemical analysis**		
	pH (1:2)	8.1	Glass electrode pH meter (Jackson,1973)
	EC (dS/m, 1:2 at 25°C)	0.31	Conductivity bridge meter (Richards,1954)
	Organic carbon (%)	0.61	Walkley and Black (1934)
	Available nitrogen (kg ha^{-1})	120	Subbiah and Asija (1956)
	Available phosphorus (kg ha^{-1})	36	Olsen's Method (Olsen *et al*., 1954)
	Available potassium (kg ha^{-1})	165	Flame Photometric Method (Richards, 1954)

The uptake of each nutrient was computed as:

$$\text{Nutrient uptake (kg ha}^{-1}) = \frac{\text{Percent nutrient in grain and straw} \times \text{Yield (kgha}^{-1})}{100}$$

Different type of nitrogen use efficiency indices were calculated based on Dobermann's (2007) techniques:-

Agronomical efficiency (AE): It represents the additional grain yield obtained from nutrient application compared to the control yield per unit of nutrient utilized.

$$\text{AE} = \frac{\text{Y} - \text{Yo}}{\text{F}}$$

Where; Y= Grain Yield of crop obtained with a given level of N applied, Y_o= Yield obtained under control, F=Amount of nutrient applied

Partial factor productivity of applied N:- The assessment of partial factor productivity (PFP) is conducted by dividing the overall grain yield achieved by the amount of nutrients applied. This can also be expressed as kilograms of harvested product per kilogram of nitrogen applied, serving as a metric for evaluating nitrogen utilization efficiency.

$$\text{PEP} = \frac{\text{Yield under treatment kg ha}^{-1}}{\text{Amount of nutrient applied kg ha}^{-1}}$$

Nitrogen harvest index (%): It is computed by following formula:

$$\text{NHI} = \frac{\text{Nitrogen uptake by grain at harvest}}{\text{Nitrogen uptake by whole plant (grain + straw)at harvest}} \times 100$$

Treatment

The following treatments were imposed:

F1: Control (No nitrogen application)

F2: 100% Recommended Dose of Nitrogen (RDN) through conventional urea

F3: 100% RDN through urea + 1 foliar spray of nano urea at 30 DAS

F4: 75% RDN through urea + 1 foliar spray of nano urea at 30 DAS

F5: 50% RDN through urea + 1 foliar spray of nano urea at 30 DAS

F6: 100 % RDN through Urea + 2 foliar sprays of Nano Urea at 30 DAS and 50 DAS

F7: 75 % RDN through Urea +2 foliar sprays of Nano Urea at 30 DAS and 50 DAS

F8: 50 % RDN through Urea +2 foliar sprays of Nano Urea at 30 DAS and 50 DAS

Application of fertilizers: - NPK were applied as per the treatment layout in the field. All plots received uniform basal application of phosphorus and potassium. Half dose of N and full P, K were applied at the time of sowing. Remaining half dose of nitrogen was top-dressed after 1st irrigation as per treatment. The recommended dose of nitrogen was applied in the form of conventional urea and nano urea as per the treatment schedule. Eight different treatments were imposed (T_1 to T_8), which varied in the source, quantity, and timing of nitrogen application. The control treatment (T_1) received no nitrogen application. The nano urea was applied as per manufacturer recommendations using a hand-held knapsack sprayer to ensure uniform coverage.

RESULTS AND DISCUSSION

Effect of integrated use of nano and non-nano urea on available soil nutrient status after harvest of wheat crop. A critical examination of data in Table 2 revealed that the availability of soil nutrients (N, P_2O_5 and K_2O) was significantly influenced by integrated use of nano and non-nano urea across both the years (2022–23 and 2023–24).The highest available nitrogen was recorded in the treatment with 100% RDN through urea + 2 foliar sprays of nano urea, with values of 127 kg ha^{-1} (2022–23) and 131 kg ha^{-1} (2023–24**)**. This was significantly higher than the control, which had the lowest nitrogen content **(**107 kg ha^{-1} and 105 kg ha^{-1}**,** respectively). The highest phosphorus (20.8 and 21.9 kg ha^{-1}) and potassium (273.5 and 279 kg ha^{-1}) were recorded in the 100% RDN + 2 nano urea sprays treatment. This was followed by 100% RDN + 1 nano spray, while the control showed the lowest P (17.1 and 17.4 kg ha^{-1}) and K (258.7 and 260.1 kg ha^{-1}).

Table 3 indicates that the combined use of nano and non-nano urea significantly enhanced nitrogen content and uptake in late-sown wheat over both years. The treatment with 100% RDN + 2 nano urea sprays (T6) consistently recorded the highest N content in grain (1.92% and 1.94%) and straw (0.25% and 0.27%). It also showed maximum N uptake in both grain and straw, with the lowest values found in the control. Slightly higher N uptake in straw was observed in 2023–24 compared to 2022–23. Similar results were confirmed by various researchers (Jagriti *et al.*, 2023).

Table 2: Effect of integrated use of nano and non-nano urea on available soil nutrient status after harvest of wheat crop.

Treatments		Available soil nutrient (kg ha^{-1})					
		N		P_2O_5		K_2O	
		2022-23	2023-24	2022-23	2023-24	2022-23	2023-24
T_1	Control	107	105	17.1	17.4	258	260
T_2	100 % RDN through Urea	119	120	19.4	20.2	265	270
T_3	100 % RDN through Urea + 1 foliar spray of Nano Urea at 30 DAS	123	125	20.0	20.9	268	270
T_4	75 % RDN through Urea +1 foliar spray of Nano Urea at 30 DAS	116	117	18.5	19.1	259	268
T_5	50 % RDN through Urea +1 foliar spray of Nano Urea at 30 DAS	112	110	17.7	17.9	259	263
T_6	100 % RDN through Urea + 2 foliar spray of Nano Urea at 30 DAS and 50 DAS	127	131	20.8	21.9	273	279
T_7	75 % RDN through Urea +2 foliar sprays of Nano Urea at 30 DAS and 50 DAS	118	121	19.0	19.4	261	269
T_8	50 % RDN through Urea +2 foliar sprays of Nano Urea at 30 DAS and 50 DAS	113	115	18.1	18.7	260	268
SEm ±		1.9	1.8	0.2	0.09	3.2	2.6
CD at 5 %		5.9	5.7	0.8	0.2	9.8	8.1
Initial soil status		129	131	26	29	266	268

Table 3: Effect of integrated use of nano and non-nano urea on N content and uptake by grain and straw of late sown wheat.

	Treatments	N content (%)				N uptake (kg ha^{-1})			
		Grain		Straw		Grain		Straw	
		2022-23	2023-24	2022-23	2023-24	2022-23	2023-24	2022-23	2023-24
T_1	Control	1.58	1.59	0.10	0.11	39.6	42.4	5.1	5.7
T_2	100 % RDN through Urea	1.87	1.89	0.23	0.24	92.1	95.5	14.8	15.7
T_3	100 % RDN through Urea + 1 foliar spray of Nano Urea at 30 DAS	1.89	1.91	0.24	0.25	93.2	96.0	15.7	16.6
T_4	75 % RDN through Urea +1 foliar spray of Nano Urea at 30 DAS	1.78	1.80	0.19	0.20	87.2	90.3	11.3	12.2
T_5	50 % RDN through Urea +1 foliar spray of Nano Urea at 30 DAS	1.67	1.69	0.14	0.15	79.3	82.0	7.5	8.2
T_6	100 % RDN through Urea + 2 foliar spray of Nano Urea at 30 DAS and 50 DAS	1.92	1.94	0.25	0.27	95.0	98.1	17.2	18.9
T_7	75 % RDN through Urea +2 foliar sprays of Nano Urea at 30 DAS and 50 DAS	1.83	1.86	0.21	0.23	89.2	92.6	13.0	14.5
T_8	50 % RDN through Urea +2 foliar sprays of Nano Urea at 30 DAS and 50 DAS	1.73	1.75	0.16	0.17	82.9	85.1	9.0	9.8
SEm (±)		0.03	0.03	0.003	0.003	1.5	1	0.1	0.2
CD at 5 %		0.09	0.09	0.009	0.008	4.8	3.2	0.5	0.6

Table 4 depcits the influence of integrated use of nano and non-nano urea on various N use efficiencies. The treatment having 50 % RDN through Urea +2 foliar sprays of Nano Urea at 30 DAS and 50 DAS resulted into maximum agronomic efficiency 13.3 and 12.6 (kg grain/kg N applied) during 2023 and 2024 respectively. However, the mean value for 2023 and 2024 was found to be highest in case of 50 % RDN through Urea +2 foliar sprays of Nano Urea at 30 DAS and 50 DAS followed by 50 % RDN through Urea +1 foliar spray of Nano Urea at 30 DAS. It can be due to small size of nano particles as they get easily absorbed through plant surface. Similar results were found by Ravi *et al.* (2024); Subramani *et al.* (2023); Sahu *et al.*, (2022).

Table 4: Effect of integrated use of nano and non-nano urea on N use efficiency of late sown wheat.

Treatments	Agronomic efficiency (kg grain/kg N applied)			Partial factor productivity of applied N			Nitrogen harvest Index (%)		
	2023	2024	Mean	2023	2024	Mean	2023	2024	Mean
Control	0	0	0	0	0	0	88.9	88.1	88.3
100 % RDN through Urea	7.5	7.2	7.4	25.9	19.3	22.9	86.16	85.8	86.0
100 % RDN through Urea + 1 foliar spray of Nano Urea at 30 DAS	7.6	7.2	7.4	26.0	26.6	26.5	85.5	85.2	85.4
75 % RDN through Urea +1 foliar spray of Nano Urea at 30 DAS	9.4	8.8	9.1	33.8	35.5	35.1	88.5	88.1	88.3
50 % RDN through Urea +1 foliar spray of Nano Urea at 30 DAS	11.8	10.9	11.3	48.5	52.1	51.7	91.3	92.3	91.8
100 % RDN through Urea + 2 foliar sprays of Nano Urea at 30 DAS and 50 DAS	7.8	8.2	8.0	26.1	24.8	25.5	84.6	83.8	84.2
75 % RDN through Urea +2 foliar sprays of Nano Urea at 30 DAS and 50 DAS	9.5	9.1	9.3	34.0	36.8	34.1	87.2	86.4	86.8
50 % RDN through Urea +2 foliar sprays of Nano Urea at 30 DAS and 50 DAS	13.3	12.6	13.0	50	52.4	50.7	90.2	89.6	89.9
SEm (±)	0.1	0.1	0.2	0.5	0.3	0.7	0.8	0.9	1.1
CD at 5 %	0.3	0.5	0.6	1.6	0.8	2.2	2.5	2.8	3.5

The treatment 50 % RDN through Urea +1 foliar spray of Nano Urea at 30 DAS was performed best (48.5 and 52.1) for partial factor productivity during 2023 and 2024 growing season which was followed by (50 and 52.4) treatment 50 % RDN through Urea +2 foliar sprays of Nano Urea at 30 DAS and 50 DAS. However, the lowest mean value during both seasons was obtained in 100 % RDN through Urea.

The maximum nitrogen harvest index was obtained in treatment having 50 % RDN through Urea +1 foliar spray of Nano Urea at 30 DAS which was statistically at par with treatment 50 % RDN through Urea +2 foliar sprays of Nano Urea at 30 DAS and 50 DAS. However, lowest nitrogen harvest index was observed in 100 % RDN through Urea + 2 foliar sprays of Nano Urea at 30 DAS and 50 DAS (84.6 and 83.8 %) for 2023 and 2024 respectively. These results were supported by Amruta *et al*. (2023).

CONCLUSIONS

The integrated use of nano and non-nano urea has been found to be significant in terms of nitrogen use efficiency and nitrogen uptake in grain and straw. The 100 % RDN through Urea + 2 foliar sprays of Nano Urea at 30 DAS and 50 DAS have significantly improved the available status of N, P and K. while in case of various nitrogen use efficiencies, the partial factor productivity and nitrogen harvest index was obtained with 50 % RDN through Urea +1 foliar spray of Nano Urea at 30 DAS. On the other hand, the 50 % RDN through Urea +2 foliar sprays of Nano Urea at 30 DAS and 50 DAS resulted into maximum agronomic efficiency under late sown wheat conditions.

FUTURE SCOPE

Integrated application of nano and non-nano urea was applied in the experiment and it was found to be effective for improving various nitrogen use efficiencies like agronomic efficiency, partial factor productivity and nitrogen harvest index. So, integrated usage of nano and non-nano urea can be used to improving the efficiency of resources and leads to sustainable farming practices.

Acknowledgments. The authors are thankful to Department of Agronomy, CCSHAU, Hisar for providing all necessary and relevant materials to conduct the experiment.
Conflict of Interest. None.

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How to cite this article: Parveen Kumar, Meena Sewhag, Danveer Singh, Sushil Kumar, Pawan Kumar, Rahul and Shivam Kumar (2025). Impact of Integrated Nano and Non-nano Urea on Nitrogen Efficiency and Uptake in Grain and Straw in Late Sown Wheat. *Biological Forum, 17*(5): 22-26.