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Effect of nano fertilizer on yield and economics of wheat (*Triticum aestivum* L.)

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Abstract
A field study was carried out at the Student's Instruction Farm, CSAUAT, Kanpur, Uttar Pradesh, India, during the Rabi season (November-May) of 2022-2023 to evaluate the impact of nano fertilizers on wheat performance. Fourteen treatments were used in the randomized block design experiment, which was triple replicated. The results showed that, the application of 75% recommended dose of nitrogen (RDN) + PK + 4 ml nano urea lit^{-1} of water spray greatly improved yield parameters and economics, such as grain yield and straw yield. This treatment exhibited favourable effects and was comparable to the 100% recommended dose of fertilizers (RDF-T_2) with 120:60:40 kg NPK ha^{-1}. Regarding yield, T_{14} had the highest grain yield (5.86 t ha^{-1}) and straw yield (8.19 t ha^{-1}), with T_2 coming in second. Though T_2 also demonstrated robust economic returns, treatment T_{14} yielded the highest gross return (₹ 1,43,802 ha^{-1}) and net return (₹ 1,01,017 ha^{-1}). The study concluded that nano fertilizers, particularly the combination of 75% RDN with nano urea, improved wheat yield and economic returns, making it a viable alternative to conventional fertilizers.

Keywords: Nano urea, wheat, yield and economics

Introduction
Wheat *(Triticum aestivum* L.) is the most important cereal belonging to the grass family Poaceae with its origin in Southwestern Asia. There are many species of wheat found in the world, which together make up the genus Triticum, the most widely grown species of wheat is common wheat (*Triticum aestivum* L.) The crop is best suited to temperate climates, however, it is mainly produced and consumed in the tropical and sub-tropical regions of the developing world. It contributes about 20% of humans' daily dietary calories and 21% of daily dietary protein intake. It is cultivated globally over a larger area i.e. 226 million ha, constituting 32% of total cereal cultivated land (USDA report, 2023). In India, wheat is the second most important food crop after rice with an area of 30.5 mha, production of 98.4 million tones, and average productivity of 3226 kg/ha. Due to environmental issues, shifting dietary habits, and fast population growth, the world's need for food is continuously rising. A staple crop, wheat (*Triticum aestivum* L.) is essential to providing for the nutritional needs of billions of people globally (FAO, 2021). However, a number of environmental and health issues, such as soil erosion, water pollution, and biodiversity loss, have been brought on by conventional agricultural methods, particularly the use of synthetic fertilizers. The development and use of alternative, sustainable farming methods, such as the use of nano fertilizers, have therefore attracted increasing attention (Raliya and Nair, 2016; Moyo *et al.*, 2019) [24, 20].

Nano fertilizers represent a promising advancement in agricultural technology, offering a more efficient and environmentally friendly alternative to conventional fertilizers (Kumar *et al.*, 2024) [10, 11]. These fertilizers utilize nano-sized particles to deliver nutrients in a controlled and targeted manner, significantly enhancing nutrient uptake by plants while minimizing leaching and environmental pollution (Bhattacharyya & Jha, 2019; Kumar *et al.*, 2023) [5, 23]. The unique physicochemical properties of these particles, such as increased solubility, greater surface area, and the capacity to penetrate plant tissues more effectively, contribute to their superior performance (Sharma *et al.*, 2020) [27]. As a result, there is growing interest in examining the impacts of nano fertilizers on various agronomic

parameters, including crop growth, yield, and overall plant health (Rana *et al.*, 2021) [25].

Numerous studies have demonstrated that nano fertilizers can significantly boost crop growth and yield, particularly in staple crops like wheat. These advanced fertilizers are known to enhance nutrient use efficiency, promote vigorous plant development, and strengthen resistance against environmental challenges such as drought and disease (Zhao *et al.*, 2018) [30]. Additionally, nano fertilizers have the potential to reduce reliance on traditional chemical fertilizers, thereby minimizing the environmental damage caused by their excessive application (Khan *et al.*, 2021; Chandra *et al.*, 2023) [8, 6]. They have also been found to decrease nitrogen leaching and improve overall fertilizer efficiency, which are key factors in promoting sustainable agriculture (Rai *et al.*, 2019; Kumar *et al.*, 2024) [23, 10, 11]. Despite the promising advantages, further research is necessary to fully understand the long-term implications of nano fertilizer use on soil health, plant physiology, and ecological balance (Amin & Faizan, 2021; Kumar *et al.*, 2022) [1, 13].

This study seeks to explore the impact of nano fertilizers on the growth and yield performance of wheat, with particular emphasis on identifying their potential benefits, associated challenges, and environmental consequences. The research will specifically assess the influence of nano fertilizers on examine yield parameters and economics. The outcomes of this investigation are expected to offer valuable insights into the practical and sustainable use of nano fertilizers to enhance wheat productivity.

Materials and Methods

A field experiment was conducted during the *Rabi* season (Nov-May) of 2022-23 at the Student's Instructional Farm, Main Campus, Chandra Shekhar Azad University of Agriculture & Technology, Kanpur, Uttar Pradesh, India. The research field is positioned at 27°32' N latitude, 88°60' E longitude, and an elevation of 1300 meters above mean sea level. This region has hot, sub-humid to humid climate. The temperature reached a maximum of 34 °C in the month of May and minimum temperature got down to 23 °C in the month of October during the crop growing season. The site receives an average annual rainfall of 1440 mm. The experiment was arranged in a randomized block design (RBD) with three replications comprised with 14 treatments viz.T_1: Control; T_2: 100% Recommended Dose of Fertilizer (RDF)-120:60:40 kg NPK ha^{-1}; T_3: 50% RDN + PK + 20 g urea L^{-1} water spray at 40 DAS; T_4: 50% RDN + PK + 20 g urea L^{-1} water spray at 60 DAS; T_5: 50% RDN + PK + 20 g urea L^{-1} water spray at 40 and 60 DAS; T_6: 75% RDN + PK + 20g urea L^{-1} water spray at 40 DAS; T_7: 75% RDN + PK + 20 g urea L^{-1} water spray at 60 DAS; T_8: 75% RDN + PK + 20 g urea L^{-1} water spray at 40 and 60 DAS; T_9: 50% RDN + PK + 4 ml nano urea L^{-1} water spray at 40 DAS; T_{10}: 50% RDN + PK + 4 ml nano ureaL^{-1} water spray at 60 DAS; T_{11}: 50% RDN + PK + 4 ml nano ureaL^{-1} water spray at 40 and 60 DAS; T_{12}: 75% RDN + PK + 4 ml nano ureaL^{-1} water spray at 40 DAS; T_{13}: 75% RDN + PK + 4 ml nano ureaL^{-1} water spray at 60 DAS; T_{14}: 75% RDN + PK + 4 ml nano ureaL^{-1} water spray at 40 and 60 DAS.

The total value of the output was quantified in monetary terms, and determined using the following formulas:

Gross returns (₹/ha) = Value of the grain (₹/ha) + Value of the straw (₹/ha)

Net returns (₹/ha) = Gross returns (₹/ha)-Total costs (₹/ha)

B: C ratio = Net returns (₹/ha) /Total cost (₹/ha)

The data generated from the characters under study for both the year was analyzed using Fisher's method of ANOVA as described by Gomez and Gomez, 1984 [32].

Results and Discussion

Yield

The results clearly demonstrate that different treatment combinations had a significant effect on wheat grain yield (Table 1 and fig. 1). The highest grain yield (5.80 t ha^{-1}) was obtained from treatment T_{14} (75% RDN + PK + 4 ml nano urea per litter spray at 40 and 60 days after sowing), followed by T_2 (100% RDF: 120:60:40 NPK kg ha^{-1}) and T_8 (75% RDN + PK + 20 g urea per litter spray at 40 and 60 DAS), with no statistically significant differences among these top treatments. Notably, treatments involving two foliar applications at both 40 and 60 DAS resulted in superior yields, irrespective of the fertilizer type used. Among the single-application timings, foliar spraying at 40 DAS was more effective than at 60 DAS across both nano and conventional fertilizer treatments. Importantly, T_{14}, which combined two nano urea sprays with a reduced basal dose, outperformed the full recommended dose treatment (T_2) by 3.75% in grain yield (Kumar *et al.*, 2020; Zhao *et al.*, 2020) [14,31] .

In terms of straw yield, T_{14} also recorded the highest output (8.19 t ha^{-1}), comparable to T_2 and T_8. Once again, dual foliar applications at 40 and 60 DAS led to the highest straw biomass, with application at 40 DAS proving more effective than at 60 DAS alone (Sharma *et al.*, 2020; Rai *et al.*, 2021) [27, 22]. Total biomass production followed a similar trend, with T_{14} (14.0 t ha^{-1}), T_2 (13.4 t ha^{-1}) and T_8 (13.0 t ha^{-1}) achieving the highest values, all significantly outperforming the control (7.45 t ha^{-1}). These findings underscore the effectiveness of dual foliar fertilizer applications especially when incorporating nano fertilizers, in maximizing wheat biomass and yield (Rai *et al.*, 2021; Singh *et al.*, 2022) [22, 29].

Economic

From an economic standpoint (Table 2 and Fig. 2) showed that the treatment T_{14} (75% RDN + PK + 4 ml nano urea per litter spray at 40 and 60 days after sowing) recorded the highest gross return (₹143,802 ha^{-1}), net return (₹101,017 ha^{-1}) and benefit-cost ratio (3.36). This was closely followed by T_2, which involved the application of the full recommended dose of fertilizers (100% RDF: 120:60:40 NPK kg ha^{-1}). In contrast, the control treatment yielded the lowest net return (₹96,484 ha^{-1}) and benefit-cost ratio (1.97). The superior yield and profitability observed in treatments incorporating nano urea can be attributed to its positive effects on photosynthesis, crop development, and nutrient use efficiency. Nano fertilizers are known to enhance the source-sink relationship, thereby optimizing nutrient uptake and promoting improved crop performance (Moyo *et al.*, 2019; Kumar *et al.*, 2020; Attri *et al.*, 2022; Zhao *et al.*, 2020) [20, 14, 2, 3, 31]. These findings align with those of Mehta *et al.* (2017) [18], who also reported enhanced economic

returns with the use of nano fertilizers. Additional studies have further supported these observations, highlighting the role of nano fertilizers in boosting agricultural profitability while ensuring efficient resource use and promoting sustainability (Khan *et al.*, 2020; Rai *et al.*, 2021) [9, 22].

Table 1: Effect of nano fertilizers on yield of wheat crop.

S. No.	Treatments	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
T_1	Control (Absolute Control)	2.81	4.64
T_2	RDN (120:60:40 kg NPK/ha)	5.59	7.89
T_3	50% RDN + PK + 20 g urealit^{-1} of water spray at 40 DAS	4.51	6.97
T_4	50% RDN + PK + 20 g urealit^{-1} of water spray at 60 DAS	4.31	6.80
T_5	50% RDN + PK + 20 g urealit^{-1}of water spray at 40 and 60 DAS	4.86	7.38
T_6	75% RDN + PK + 20 g urealit^{-1} of water spray at 40 DAS	5.12	7.40
T_7	75% RDN + PK + 20 g urealit^{-1}of water spray at 60 DAS	4.94	7.39
T_8	75% RDN + PK + 20 g urealit^{-1}of water spray at 40 and 60 DAS	5.40	7.68
T_9	50% RDN + PK + 4 ml nano urealit^{-1}of water spray at 40 DAS	4.71	7.20
T_{10}	50% RDN + PK + 4 ml nano urealit^{-1}of water spray at 60 DAS	4.44	6.95
T_{11}	50% RDN + PK + 4 ml nano urealit^{-1}of water spray at 40 and 60 DAS	4.90	7.36
T_{12}	75% RDN + PK + 4 ml nano urealit^{-1}of water spray at 40 DAS	5.24	7.54
T_{13}	75% RDN + PK + 4 ml nano urealit^{-1}of water spray at 60 DAS	5.06	7.51
T_{14}	75% RDN + PK + 4 ml nano urealit^{-1}of water spray at 40 and 60 DAS	5.80	8.19
SEm±		1.72	2.05
LSD (P=0.05)		5.00	5.97.

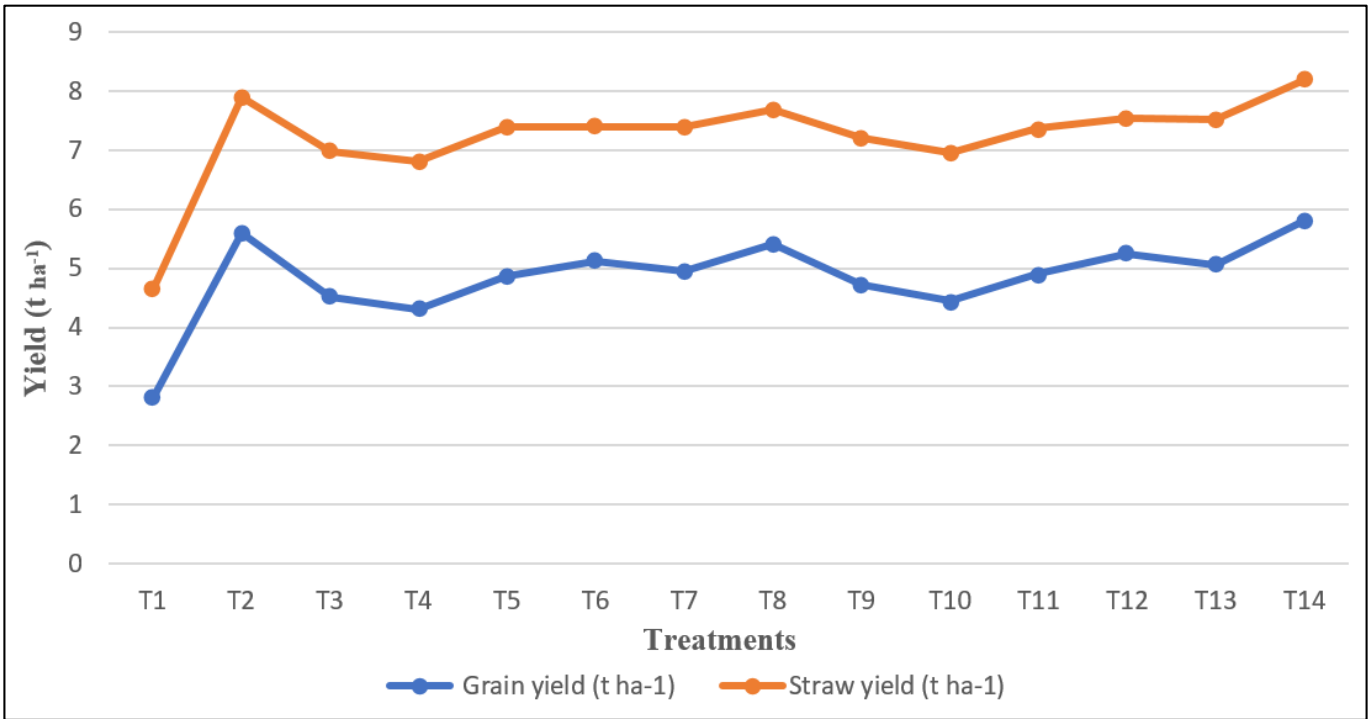

Fig 1: Effect of nano fertilizers on yield of wheat crop.

Table 2: Effect of nano fertilizers on economic of different treatments.

S. No.	Treatments	Cost of cultivation (₹ ha^{-1})	Gross return (₹ ha^{-1})	Net return (₹ ha^{-1})	B: C ratio
T_1	Control (Absolute Control)	36282	71497	35215	1.97
T_2	RDN (120:60:40 kg NPK/ha)	41736	138583	96848	3.32
T_3	50% RDN + PK + 20 g urealit^{-1} of water spray at 40 DAS	41044	113458	72414	2.76
T_4	50% RDN + PK + 20 g urealit^{-1} of water spray at 60 DAS	41044	108615	67571	2.65
T_5	50% RDN + PK + 20 g urealit^{-1}of water spray at 40 and 60 DAS	41140	121811	80671	2.96
T_6	75% RDN + PK + 20 g urealit^{-1} of water spray at 40 DAS	41441	127344	85904	3.07
T_7	75% RDN + PK + 20 g urealit^{-1}of water spray at 60 DAS	41441	123612	82172	2.98
T_8	75% RDN + PK + 20 g urealit^{-1}of water spray at 40 and 60 DAS	41537	134075	92538	3.23
T_9	50% RDN + PK + 4 ml nano urealit^{-1}of water spray at 40 DAS	41668	118166	76498	2.84
T_{10}	50% RDN + PK + 4 ml nano urealit^{-1}of water spray at 60 DAS	41668	111897	70230	2.69
T_{11}	50% RDN + PK + 4 ml nano urealit^{-1}of water spray at 40 and 60 DAS	42388	122670	80282	2.89
T_{12}	75% RDN + PK + 4 ml nano urealit^{-1}of water spray at 40 DAS	42065	130404	88340	3.10
T_{13}	75% RDN + PK + 4 ml nano urealit^{-1}of water spray at 60 DAS	42065	126410	84346	3.01
T_{14}	75% RDN + PK + 4 ml nano urealit^{-1}of water spray at 40 and 60 DAS	42785	143802	101017	3.36

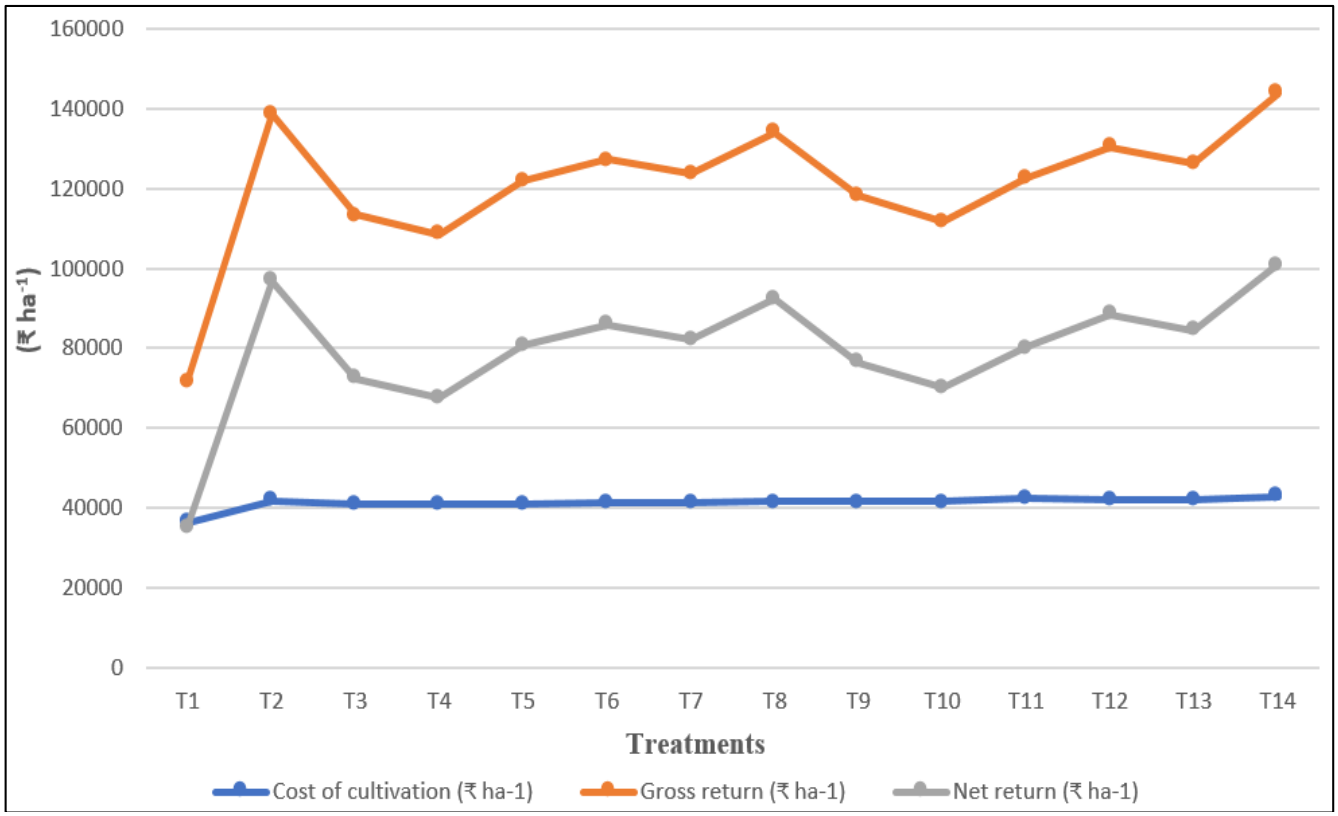

Fig 2: Effect of nano fertilizers on economic of different treatments.

Conclusion

The present study concluded that the application of treatment T_{14}, which involved 75% of the Recommended Dose of Nitrogen (RDN) along with Phosphorus and Potassium (PK) and a foliar spray of 4 ml nano urea per litre of water applied at 40 and 60 days after sowing (DAS), significantly enhanced crop yield and income. This treatment recorded the highest grain and straw yields among all the treatments evaluated, clearly demonstrating the potential of nano urea in improving both productivity and profitability in crop production. In addition to yield improvement, T_{14} also achieved the maximum economic returns, emphasizing its cost-effectiveness and sustainability. The results suggest that integrating nano urea into nutrient management practices enhances resource use efficiency by reducing the need for conventional nitrogen fertilizers while maintaining or even boosting output. This makes nano urea a promising component in sustainable and precision agriculture practices.

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