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Foliar urea and nano urea applications: impacts on growth, chlorophyll content, yield attributes and economics of wheat (*Triticum aestivum* L.)

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Abstract
Wheat, a vital staple cereal crop feeding a large share of the global population, requires efficient nutrient management; however, limited comparative research has evaluated the physiological, agronomic and economic impacts of foliar-applied conventional urea and nano urea under field conditions. To address this issue, a study was conducted during the *rabi* season of 2023-2024 at the Instructional Farm, Post Graduate Institute, Mahatma Phule Krishi Vidyapeeth, Rahuri, with a view to study the "Response of foliar application of urea and nano urea on yield and nutrient uptake of wheat under irrigated condition". The experiment was conducted in randomized block design and treatments were consisted of 12 levels of nutrient combination with 3 replications. The application of the general recommended dose of fertilizers (GRDF) at 120:60:40 kg N:P_2O_5:K_2O with 10 tons of farmyard manure (FYM) per hectare yielded the most beneficial results for the wheat crop. This treatment resulted in the highest significant values for plant population, chlorophyll content, and yield contributing characters, including the length of the ear, number of spikelets and grains per ear, and grain weight. Economically, the GRDF treatment also provided the highest gross monetary returns (113,955 ₹ ha^{-1}), net monetary returns (64,801 ₹ ha^{-1}), and B-C ratio of 2.32. However, the study concluded that treatments involving 75% of the recommended nitrogen dose applied to the soil, combined with a 4% or 6% foliar spray of urea, performed on par with the GRDF treatment. This suggests a potential to save 25% of the nitrogen fertilizer for wheat while achieving comparable results.

Keywords: Nano urea, plant population, chlorophyll content, yield, economics, B-C ratio

Introduction
Wheat (*Triticum aestivum* L.) is an important cereal crop belongs to family "Poaceae" and genus "Triticum". It is the world's most important cereal crop, accounting for 30% of all cereal food produced globally. It occupies around 220.7 million hectares of area across the world with the annual production of 783.43 million tones with the productivity of 3.55 metric tons per hectare (USDA, 2023). It has been under cultivation in the Indian subcontinent from pre-historic times and is an integral part of country's economy and food security. Wheat accounts for almost 55% of all carbohydrates and 20% of all dietary calories consumed globally (Graur and Breiman, 1995). Wheat is grown in India on 31.23 million hectares and produces of 112.92 million ton with national average productivity of 3615 kg ha^{-1} during 2023-24 (IIWBR, Karnal, 2023-24).
Nitrogen is the universal deficient macro nutrient in Indian soil (Dey and Sekhon 2016). Wheat is highly responsive to nitrogen fertilization and is sensitive to insufficient nitrogen. Macro nutrients like N, P and K in sufficient quantity throughout the growing season are essential for optimum plant growth (Haque *et al*., 2001) [3]. Nitrogen is a fundamental component of protein and an essential part of the chlorophyll molecule, which is crucial for photosynthesis. Consequently, the nitrogen supply determines the amount of protein, chlorophyll, and protoplasm available, which ultimately influences leaf area and cell size. When a plant has an adequate supply of nitrogen, it grows at an optimal rate and its leaves remain a healthy dark green. In contrast, a nitrogen deficiency leads to light green leaves, reduced tillering, and low protein synthesis, all of which reduce the crop's growth and yield.

Materials and Methods

The field experiment entitled "Response of foliar application of urea and nano urea on growth, yield and quality of wheat under irrigated condition" was conducted at Post Graduate Institute Farm, MPKV, Rahuri during *rabi* 2023-24. The experiment consists of 12 treatments *viz.*, T_1: Absolute control; T_2: General recommended dose of fertilizers (120:60:40 N:P_2O_5:K_2O Kg ha^{-1} + 10 t ha^{-1} of FYM); T_3: 75% RDN through soil + foliar spray of nano urea @ 0.2%; T_4: 75% RDN through soil + foliar spray of urea @ 2%; T_5: 75% RDN through soil + foliar spray of nano urea @ 0.4%; T_6: 75% RDN through soil + foliar spray of urea @ 4%; T_7: 75% RDN through soil + foliar spray of nano urea @ 0.6%; T_8: 75% RDN through soil + foliar spray of urea @ 6%; and T_9: 50% RDN through soil + foliar spray of nano urea @ 0.4%; T_{10}: 50% RDN through soil + foliar spray of urea @ 4%; T_{11}: 50% RDN through soil + foliar spray of nano urea @ 0.6%; T_{12}: 50% RDN through soil + foliar spray of urea @ 6%. Potassium and Phosphorus will be applied through MoP and single super phosphate; P_2O_5 and K_2O applied as per the recommended dose of fertilizer for wheat except T_1.

The experiment was laid out in randomized block design (RBD) with three replications. Line sowing of wheat seeds was done on flat beds at spacing of 20 cm between rows. The soil was clay loam in texture, low in available nitrogen (191.6 kg ha^{-1}), medium in available phosphorus (18.3 kg ha^{-1}) and high in potassium (436.6 kg ha^{-1}). The mean available nitrogen, phosphorus and potassium content in soil after harvest of wheat crop were 210.5, 45.4 and 418.2 kg ha^{-1} respectively. The soil was slightly alkaline in reaction (pH 8.16) with medium in organic carbon content (0.57%). The pH is measured by Potentiometry and electrical conductivity measured by Conductometry method. The organic carbon estimated by Wet oxidation method Walkey and Black (Nelson and Sommer, 1982) [6]. The available Nitrogen, Phosphorus and potassium measured by Alkaline permanganate method (Subbiah and Asija, 1956) [9], Olsen method 0.5 M $NaHCO_3$ (Watanabe and Olsen, 1965) [14] and Flame photometry method (Jackson, 1973) [5] respectively.

The recommended dose of fertilizer (120:60:40 N:P_2O_5:K_2O kg ha^{-1} + 10 t ha^{-1} of FYM) was applied 60:40 kg ha^{-1} P_2O_5:K_2O as a basal through SSP and MOP in treatment T_2 to T_{12}. N applied as per treatments. Thereafter, foliar application of urea and nano urea was done at 20 and 35 days after sowing, respectively.

Results and Discussion

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads:

Plant Population

Table 1: Effect of foliar application of urea and nano urea on plant population of wheat

Tr. No.	Treatment	Plant population (m^{-1})			
		At 15 DAS	Per cent	At harvest	Per cent
T_1	Absolute control	47.87	95.73	45.70	91.41
T_2	General recommended dose of fertilizers (120:60:40 N: P_2O_5:K_2O Kg ha^{-1} + 10 t ha^{-1} of FYM)	49.35	98.70	48.42	96.83
T_3	75% RDN through soil + foliar spray of nano urea @ 0.2%	49.24	98.48	47.59	95.19
T_4	75% RDN through soil + foliar spray of urea @ 2%	49.29	98.58	47.82	95.63
T_5	75% RDN through soil + foliar spray of nano urea @ 0.4%	49.27	98.54	47.72	95.45
T_6	75% RDN through soil + foliar spray of urea @ 4%	49.32	98.63	48.10	96.19
T_7	75% RDN through soil + foliar spray of nano urea @ 0.6%	49.30	98.61	47.97	95.93
T_8	75% RDN through soil + foliar spray of urea @ 6%	49.33	98.67	48.57	97.15
T_9	50% RDN through soil + foliar spray of nano urea @ 0.4%	48.86	97.71	46.76	93.52
T_{10}	50% RDN through soil + foliar spray of urea @ 4%	49.04	98.08	47.22	94.43
T_{11}	50% RDN through soil + foliar spray of nano urea @ 0.6%	48.99	97.98	47.10	94.2
T_{12}	50% RDN through soil + foliar spray of urea @ 6%	49.18	95.73	47.29	94.58
	S.E. m ±	0.91	---	1.03	---
	C.D. at 5%	NS	---	NS	---
	General mean	49.09	98.16	47.52	95.04

The data presented in the table 1 revealed that initial plant count was recorded in various treatments in net plot and presented in this table 1. From this table, it was observed that mean initial plant count of wheat was 49.09 of the theoretical plant population. This indicates the plant population was uniform and optimum throughout the experimental plot. It was observed that mean initial plant count of wheat was 47.52 of the theoretical plant population. This indicates the plant population was uniform and optimum throughout the experimental plot.

Plant population not differs significantly due to the different foliar application; hence there was no effect on plant population at harvest. Rapid and efficient response is given by the nutrients applied through general recommended dose of fertilizers. There was cumulative effect in the more accumulation of photosynthates and its translocation from sink to reproductive part like grain of wheat. These results are similar with the results reported by Wagan *et al.* (2002) [13], Vikas *et al.* (2019), Yadav *et al.* (2021) [15], Dhaker *et al.* (2022), Rawate *et al.* (2022) [8] and Ojha *et al.* (2023) [7].

Total Chlorophyll Content (SPAD)

Table 2: Effect of foliar application of urea and nano urea on total chlorophyll content

Sr. No.	Treatment Detail	Total chlorophyll content (SPAD)		
		30 DAS	60 DAS	90 DAS
T_1	Absolute control	19.64	28.38	23.95
T_2	General recommended dose of fertilizers (120:60:40 N: P_2O_5:K_2O Kg ha^{-1} + 10 t ha^{-1} of FYM)	25.21	46.53	42.03
T_3	75% RDN through soil + foliar spray of nano urea @ 0.2%	22.93	37.53	33.21
T_4	75% RDN through soil + foliar spray of urea @ 2%	23.49	41.31	36.81
T_5	75% RDN through soil + foliar spray of nano urea @ 0.4%	22.95	39.09	34.59
T_6	75% RDN through soil + foliar spray of urea @ 4%	24.43	43.57	39.07
T_7	75% RDN through soil + foliar spray of nano urea @ 0.6%	23.67	42.46	36.96
T_8	75% RDN through soil + foliar spray of urea @ 6%	24.83	44.95	40.50
T_9	50% RDN through soil + foliar spray of nano urea @ 0.4%	20.09	31.51	27.01
T_{10}	50% RDN through soil + foliar spray of urea @ 4%	21.90	34.77	30.27
T_{11}	50% RDN through soil + foliar spray of nano urea @ 0.6%	21.12	33.73	29.23
T_{12}	50% RDN through soil + foliar spray of urea @ 6%	22.08	35.72	31.22
	S.E. m ±	1.20	1.38	1.54
	C.D at 5%	NS	4.03	4.50
	General mean	22.69	39.20	33.74

The data on total chlorophyll content (SPAD values) as influenced by different treatments are presented in table 2. The data outlined in table 2 indicated that total chlorophyll content (SPAD values) differed significantly at 60 and 90 DAS due to the treatments of foliar application of nutrients. The mean Chlorophyll Content was 22.69, 39.20 and 33.74 (SPAD) at 30, 60 and 90 DAS, respectively.

There was a non-significant difference among different treatments at 30 DAS. While, at 60, 90 DAS and at harvest, the application of treatment T_6 i.e. general recommended dose of fertilizers (120:60:40 N: P_2O_5:K_2O Kg ha^{-1} + 10 t ha^{-1} of FYM) recorded significantly maximum total chlorophyll content (25.21, 46.53 and 42.03 SPAD, respectively). Chlorophyll production is the relative process of effective utilization of the resources in better crop production environment. When wheat crop is subjected with foliar application of urea and nano urea, it results into higher total chlorophyll content because there was sufficient availability of nutrient to the wheat crop that results in increase in photosynthetic activities.

The current experiment's results are consistent with those published by Surve and Bhosale (2015) [10], Wagan *et al*. (2002) [13], Vikas *et al*. (2019), Yadav *et al*. (2021) [15], Rawate *et al.* (2022) [8] and Ojha *et al.* (2023) [7].

Yield Contributing Characters

Table 3: Effect of foliar application of urea and nano urea on yield contributing characters of wheat

Tr. No.	Treatment Detail	Length of ear (cm)	Number of spikelet ear^{-1}	Number of grains ear^{-1}	Weight of grains ear^{-1} (g)	Test weight g (1000 seed)
T_1	Absolute control	6.85	11.69	32.79	1.23	36.68
T_2	General recommended dose of fertilizers (120:60:40 N: P_2O_5: K_2O Kg ha^{-1} + 10 t ha^{-1} of FYM)	9.16	16.40	44.56	1.66	40.93
T_3	75% RDN through soil + foliar spray of nano urea @ 0.2%	7.53	13.73	36.77	1.42	38.22
T_4	75% RDN through soil + foliar spray of urea @ 2%	7.94	14.33	39.73	1.48	39.53
T_5	75% RDN through soil + foliar spray of nano urea @ 0.4%	7.71	13.98	37.01	1.45	38.83
T_6	75% RDN through soil + foliar spray of urea @ 4%	8.51	15.01	41.87	1.58	40.37
T_7	75% RDN through soil + foliar spray of nano urea @ 0.6%	8.14	14.82	41.07	1.50	39.83
T_8	75% RDN through soil + foliar spray of urea @ 6%	8.76	15.12	43.02	1.61	40.63
T_9	50% RDN through soil + foliar spray of nano urea @ 0.4%	7.07	12.15	34.06	1.28	37.73
T_{10}	50% RDN through soil + foliar spray of urea @ 4%	7.33	12.78	35.87	1.36	38.07
T_{11}	50% RDN through soil + foliar spray of nano urea @ 0.6%	7.20	12.39	34.82	1.33	36.93
T_{12}	50% RDN through soil + foliar spray of urea @ 6%	7.48	13.09	36.12	1.40	38.20
	S.E. m ±	0.32	0.52	1.25	0.05	1.82
	C.D. at 5%	0.94	1.53	2.59	0.15	NS
	General mean	7.81	13.79	38.14	1.44	38.83

The data in respect of yield contributing characters of wheat as influenced by different treatments during *rabi* season of 2023-2024 are presented in table 3. Among yield contributing characters, significantly higher length of ear (9.16 cm), number of spikelets ear^{-1} (16.40), number of grains ear^{-1} (44.56), weight of grains ear^{-1} (1.66 g) and test weight (40.93 g) were obtained with application of general recommended dose of fertilizers (120:60:40 N: P_2O_5: K_2O Kg ha^{-1} + 10 t ha^{-1} of FYM). The next best treatment was application of 75% RDN through soil + foliar spray of urea @ 6% recorded yield attributes *viz*., length of ear (8.76 cm), number of spikelets ear^{-1} (15.12), number of grains ear^{-1} (43.02), weight of grains ear^{-1} (1.61 g) and test weight (40.63 g) followed by application of 75% RDN through soil + foliar spray of urea @ 4% produced length of ear (8.51 cm), number of spikelets ear^{-1} (15.01), number of grains ear^{-1} (41.87), weight of grains ear^{-1} (1.58 g) and test weight (40.37 g).

These results are similar with the results reported by Vikas *et al*. (2019), Yadav *et al*. (2021) [15], Surve and Bhosale (2015) [10],

Wagan *et al*. (2002) [13], Rawate *et al.* (2022) [8] and Ojha *et al.* (2023) [7].

Economic studies

Table 4: Effect of foliar application of urea and nano urea on economics i.e. gross monetary, net monetary return, cost of cultivation and B-C ratio of wheat

Tr. No.	Treatments	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})	Gross monetary returns (₹ ha^{-1})	Cost of cultivation (₹ ha^{-1})	Net monetary return (₹ ha^{-1})	B: C
T_1	Absolute control	21.3	37.1	60730	27295	33435	2.22
T_2	General recommended dose of fertilizers (120:60:40 N: P_2O_5:K_2O Kg ha^{-1} + 10 t ha^{-1} of FYM)	41.4	52.1	113955	49154	64801	2.32
T_3	75% RDN through soil + foliar spray of nano urea @ 0.2%	34.8	43.1	95602	50015	45587	1.91
T_4	75% RDN through soil + foliar spray of urea @ 2%	37.8	46.4	103780	49540	54240	2.09
T_5	75% RDN through soil + foliar spray of nano urea @ 0.4%	35.8	44.2	98240	50557	47683	1.94
T_6	75% RDN through soil + foliar spray of urea @ 4%	40.2	48.6	110328	49608	60721	2.22
T_7	75% RDN through soil + foliar spray of nano urea @ 0.6%	38.9	47.7	106717	51099	55617	2.09
T_8	75% RDN through soil + foliar spray of urea @ 6%	40.9	50.7	112482	49676	62806	2.26
T_9	50% RDN through soil + foliar spray of nano urea @ 0.4%	27.7	40.1	77337	50115	27221	1.54
T_{10}	50% RDN through soil + foliar spray of urea @ 4%	31.9	42.1	88113	49166	38947	1.79
T_{11}	50% RDN through soil + foliar spray of nano urea @ 0.6%	29.3	41.7	81663	50658	31006	1.61
T_{12}	50% RDN through soil + foliar spray of urea @ 6%	32.7	42.8	90195	49234	40961	1.83
	S.E. m ±	0.8	1.2	2297.07	-	2297.07	-
	C.D. at 5%	2.3	3.6	6737.5	-	6737.5	-
	General mean	34.4	44.7	94928.5	48010	46918.8	1.99

The data in respect of economics i.e. gross monetary, net monetary return, cost of cultivation and B: C of wheat as influenced by different treatments during *rabi* season of 2023-2024 are presented in table 4. The mean gross monetary, cost of cultivation and net monetary return of wheat were 94928.5, 48010 and 46918.8 ₹ ha^{-1} respectively obtained during investigation. The mean grain and straw yield of wheat (34.4 and 44.7 q ha^{-1}, respectively) were obtained during investigation. In the present investigation, significantly higher gross monetary returns (₹ 113955 ha^{-1}) net monetary returns (₹ 64801 ha^{-1}) and B: C (2.32) was obtained with application of general recommended dose of fertilizers (120:60:40 N: P_2O_5: K_2O kg ha^{-1} + 10 t ha^{-1} of FYM) as compared to other treatments. It was at par with application of 75% RDN through soil + foliar spray of urea @ 6% with gross monetary returns (₹ 112482 ha^{-1}), net monetary returns (₹ 62806 ha^{-1}) and B: C (2.26) as well as application of 75% RDN through soil + foliar spray of urea @ 4% with gross monetary returns (₹ 110328 ha^{-1}), net monetary returns (₹ 60721 ha^{-1}) and B: C (2.22). While the application of absolute control gives minimum gross returns (₹ 60730 ha^{-1}), net monetary returns (₹ 33435 ha^{-1}) and application of 50% RDN through soil + foliar spray of nano urea @ 0.4% gives minimum B: C (1.54).

These results are in collaboration with findings of Wagan *et al*. (2002) [13], Vikas *et al*. (2019), Yadav *et al*. (2021) [15], Dhaker *et al*. (2022), Rawate *et al*. (2022) [8] and Ojha *et al*. (2023) [7].

Conclusion

The application of the general recommended dose of fertilizers (GRDF) at 120:60:40 kg N:P_2O_5:K_2O per hectare with 10 tons of farmyard manure (FYM) per hectare, was found to be the most beneficial for the wheat crop. This treatment resulted in the highest significant values for plant population, chlorophyll content, yield contributing characters and economic returns compared to all other treatments.

However, treatments involving 75% of the recommended nitrogen dose applied to the soil, combined with a 4% or 6% foliar spray of urea at the crown root initiation (CRI) and tillering stages, performed on par with the GRDF treatment. This indicates a potential to save 25% of the nitrogen fertilizer for the wheat crop while achieving comparable results

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Conflict of Interest

The authors declare there are no conflict of interest relevant to this article.

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