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Nano urea effects on nitrogen use efficiency and yield potential of wheat under limited irrigation

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Abstract
Effect of nano urea was tested under field condition at WRU, Dr. PDKV, Akola (Maharashtra State) during the *rabi* 2023-2024. The experiment was laid out in randomize block design (RBD) having ten different treatment combinations with three replications. The treatment includes T_1- One spray of Nano urea (NU) (4 ml/litre) at highest tillering (30-35 DAS), T_2-Two spray of NU (4 ml/litre) at tillering (30-35 DAS) and jointing (40-45 DAS),T_3- 80 Kg ha^{-1} N (1/3rd basal, 2/3rd CRI – 80 Kg ha^{-1} N), T_4- 80 Kg ha^{-1} N + one spray of NU (4 ml/litre) at tillering (30-35 DAS), T_5- 80 Kg ha^{-1} N + two spray of NU (4 ml/litre) at tillering (30-35 DAS) and jointing (40-45 DAS), T_6 - 80 Kg ha^{-1} N + one spray of urea (2%) at tillering (30-35 DAS), T_7 - 80 Kg ha^{-1} N + two spray of urea (2%) at tillering (30-35 DAS) and jointing(40-45 DAS), T_8 - 80 Kg ha^{-1} N + one spray of urea (2%) + NU (4 ml/litre) at tillering (30-35 DAS), T_9 - 80 Kg ha^{-1} N + one spray of urea (2%) +DAP (2%) + NU (4 ml/litre) at tillering (30-35 DAS), T_{10}- Control (Zero nitrogen). The soil of experimental site was slightly clayey in texture with pH (8.1), organic carbon (0.52%), electric conductivity (0.32 dSm^{-1}), available N (191 kg ha^{-1}), Available P (17.32 kg ha^{-1}) and available K (359 kg ha^{-1}). Significantly higher straw yield (5559 kgha^{-1}) was recorded with treatment T_6 - 80 Kg ha^{-1} N+ one spray of urea (2%) at tillering (30-35 DAS). Harvest index was found to be non-significant with respect to different treatments. Treatment T_7 (80 Kg ha^{-1} N + two spray of urea (2%) at tillering and jointing had recorded highest grain yield (5098 kg ha^{-1}), highest uptake of nitrogen, highest NUE (73.48%), nitrogen (1.8%) and protein content (10.26%) in grain. Maximum gross monetary return, net monetary return and B:C ratio was observed in the above treatment.

Keywords: Nano urea, wheat, irrigation, efficiency

Introduction
Wheat (*Triticum aestivum* L.) cultivated worldwide is hexaploid bread wheat, constituting approximately 95 per cent of the global wheat production. This common or bread wheat variety is highly prized for its suitability in bread making. The crop is cultivated across 23.61 million hectares, with an annual yield of approximately 44.25 million tonnes. For the 2022-2023 period, wheat production is projected to reach a record high of 110.55 million tonnes. This marks an increase of 2.81 million tonnes compared to the previous year's production of 107.74 million tonnes, and a rise of 4.82 million tonnes over the average wheat production of 105.73 million tonnes (Anonymous, 2024) [1]. State-wise comparison of area and production shows that eastern state like UP, Punjab, MP and Haryana were the highest contributor to national production. Maharashtra ranks eighth with in annual production of 2473.71 thousand tonnes in year 2021-22. Wheat is primarily cultivated for human consumption, although approximately 10 per cent of the crop is set aside for seed propagation and industrial applications, including the production of starch, malt, dextrose, and gluten. The wheat grain is a rich source of essential nutrients, comprising approximately 12 per cent moisture. Its composition includes carbohydrates (comprising 60-80 per cent mainly as starch), proteins (ranging from 8-15 per cent) containing sufficient quantities of all essential amino acids except lysine, 1 tryptophan, and methionine, fats (approximately 1.5-2 per cent), minerals (about 1.5-2 per cent), vitamins (such as those from the B complex and vitamin E), and approximately 2.2 per cent crude fibres. As projected by the FAO of the UN, the world population is expected to reach nearly 10 billion by 2050. This

growth, alongside constrained land availability and an increase in extreme weather events, coupled with the current inefficient resource allocation (e.g., water, energy, and nutrients), poses a significant challenge for agriculture and the entire food supply chain in meeting future global food demand sustainably (FAO, 2019) [5]. The extensive use of traditional agrochemicals has shown unsustainable environmental consequences. Recent assessments indicate that approximately 30 per cent of total crop yield can be attributed to fertilizer usage, with the remaining 70 per cent relying on the effective implementation of various factors with agricultural commodities. However, a significant portion of applied fertilizers either become fixed in the soil or are lost to the environment through processes such as leaching, volatilization and water runoff. Specifically, between 50 to 70 per cent of nitrogenous fertilizers administered through conventional methods are either lost as water-soluble nitrates, gaseous ammonia, nitrogen oxides, or are assimilated as minerals in the soil via microbial activity. Nitrogen stands out as the most critical nutrient for crop productivity and plays a pivotal role in agriculture. However, the use of urea has been associated with reduced fertilizer efficiency, leading to increased costs. Paradoxically, the imbalanced and indiscriminate application of inorganic fertilizers has negatively impacted nutrient availability to plants, soil fertility, and soil health, resulting in decreased crop productivity and contributing to chronic human health issues. Fertilizers, which are nutrients contained within Nano porous materials at a size of 10^{-9} meters, coated with a thin polymer film are referred to as Nano fertilizers. Their application offers the advantage of specifically releasing nutrients within the plant, thereby minimizing losses and preventing rapid alterations in their chemical properties. Nano-fertilizers can gradually release their nutrients over a period of 40 to 50 days, contrasting with synthetic fertilizers, which achieve similar release within 4 to 10 days. Consequently, urea fertilizers can lose over 70 per cent of their nitrogen content shortly after field application due to leaching and volatilization, leaving less than 19-20 percent readily available for plant uptake A single Nano urea particle measures approximately 30 nanometers in diameter (IFFCO, 2021) [6], possessing a surface area to volume ratio approximately 10,000 times greater than that of regular urea. Due to its remarkably minute size and surface-penetrating characteristics, Nano urea is readily intake by the plants when applied as a spray on their leaves. These nano-particles have the ability to penetrate to specific areas within the plant where nitrogen is required, facilitating the controlled release of nutrients. This targeted and controlled release mechanism inherent in Nano-formulated agricultural inputs helps to mitigate excess runoff, prevent eutrophication, and eliminate residual contamination, contributing to improved environmental sustainability. Nano-fertilizers are formulated with nutrients and growth promoters enclosed within Nano-scale polymers, facilitating the gradual release of essential nutrients to crops in a phased manner. By enhancing nutrient use efficiency, these nanoscale polymers ensure targeted and efficient nutrient delivery to crops throughout their growth cycles. With the aim of offering farmers a practical and economically viable solution to sustainably enhance crop production, improve crop quality, and optimize resource utilization, the present study investigates the effects of eco-friendly granular and foliar Nano-N on wheat crops. The evaluation of these environmentally sustainable Nano-fertilizers holds significant promise for agricultural practices. In agricultural systems, sustainable efforts aim to synchronize nutrient availability and improve Nitrogen Use Efficiency (NUE) values without further degradation of surrounding environments. Nano urea emerges as a potential solution to enhance overall NUE values by facilitating a more controlled and gradual nutrient release process. Experiment was conducted with objectives to maximize wheat productivity by optimizing nitrogen dose and nano urea under restricted irrigation situations.

Materials and Methods

The present study was conducted during rabi 2023-24 at Plot No. 7 of Wheat Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth (Dr. PDKV), Akola, Maharashtra. Soil characteristics of experimental place was clayey in texture, consist of clay (59.30%), silt (27.50%) and sand (13.20%). The Available nitrogen (191.4 Kg ha^{-1}), phosphorus (17.32 Kg ha^{-1}) (Olsen, 1954) [10] and potassium (359.19 kg ha^{-1}). The organic carbon (4.4 g kg^{-1}), soil pH 8.1 with EC (0.32 dSm^{-1}). Akola is situated in the sub-tropical zone at the latitude of 200.42' North and longitude of 720.02' East. The altitude of the place is 307.41meter higher than the mean sea level. Climate is semi-arid and characterized by three distinct season, the mean daily evaporation reaches as high as 16.8 mm in the May and as low as 4.3 mm in the August. The mean wind speed varies from 4.7 km hr^{-1} during October to 17.6 km hr^{-1} during June. Relative humidity attains the maximum value (74-87%) throughout SW monsoon season and the minimum (30-40%) during summer months. Experimental design used as Randomized Block Design (RBD). The treatment details includes T_1- One spray of NU (4 ml/litre) at highest tillering (30-35 DAS), T_2-Two spray of NU (4 ml/litre) at tillering (30-35 DAS) and jointing (40-45 DAS),T_3- 80 Kg ha^{-1} N (1/3rd basal, 2/3rd CRI – 80 Kg ha^{-1} N), T_4- 80 Kg ha^{-1} N + one spray of NU (4 ml/litre) at tillering (30-35 DAS), T_5- 80 Kg ha^{-1} N + two spray of NU (4 ml/litre) at tillering (30-35 DAS) and jointing (40-45 DAS), T_6 - 80 Kg ha^{-1} N + one spray of urea (2%) at tillering (30-35 DAS), T_7 - 80 Kg ha^{-1} N + two spray of urea (2%) at tillering (30-35 DAS) and jointing(40-45 DAS), T_8 - 80 Kg ha^{-1} N + one spray of urea (2%) + NU (4 ml/litre) at tillering (30-35 DAS), T_9 - 80 Kg ha^{-1} N + one spray of urea (2%) +DAP (2%) + NU (4 ml/litre) at tillering (30-35 DAS), T_{10}- Control (Zero nitrogen). Quantity of P and K will be as per recommended level in all treatments. Sand, silt and clay Sand, silt and clay was determined by Bouyucous hydrometer method (Piper, 1966) [12]. Cultivar AKAW-4627: This variety is suitable for Irrigated late sown conditions. Very early maturing (96 days) variety with semi dwarf stature. Statistical analysis with coefficient of variation were calculated among selected characters in order to establish cause and effect relationship. These calculations were all completed using the usual statistical method recommended by Panse and Sukhatme (1989) [11].

Results and Discussion

Results indicate that (Table 1) the significantly highest plant height (86.93 cm), no of tiller $plant^{-1}$ (9.7) and dry matter plant (15.4 g) at harvest was recorded in the treatment T_7 - 80 Kg ha^{-1} N + two spray of urea (2%) at tillering (30-35 DAS) and jointing (40-45 DAS) and was at par with only treatment T_9 - 80 Kg ha^{-1} N + one spray of urea (2%) +DAP (2%) + NU (4 ml/litre) at tillering (30-35 DAS). Highest test weight (40.37 g) was recorded with T_8 - 80 Kg ha^{-1} N + one spray of urea (2%) + NU (4 ml/litre) at tillering (30-35 DAS). Foliar use of nano-urea fertilizers significantly improved the dry matter accumulation. The reason might be as nano urea absorbed easily with high efficiency as a result of higher surface area and enhanced activity might have resulted in improved the nutrient uptake in plants which eventually led to the cumulative increase in photosynthesis and finally in the growth parameter like plant height, leaf area, number of tillers m^{-1} row. Similar finding was reported by Morsy *et al*. (2021) [9] they observed the impact of the previous crop, sowing techniques, and nano fertilizers on the growth, production and quality of bread wheat at the Abu Simbel (Egypt). The foliar application of nano fertilizer with 500 ml fed^{-1} gave the maximum average values for plant height, number of spike $plant^{-1}$, number of leaves $plant^{-1}$ and flag leaf area in 2018-19 and 2019- 20 seasons, respectively. Similar finding was noted by Al-Juthery *et al*. (2019) [2] and Mehta and Bharat (2019) [8].

Table 1: Plant height, No of tillers $plant^{-1}$, Dry matter $plant^{-1}$ and 1000 grain weight of wheat as influence by various treatments.

Treatments	Plant height (cm)	No of tillers $plant^{-1}$	Dry matter $plant^{-1}$ (g)	1000 grain weight (g)
T_1- One spray of NU (4 ml/litre) at maximum tillering (30-35 DAS)	67.93	8.6	10.8	40.10
T_2-Two spray of NU (4 ml/litre) at tillering (30-35 DAS) and jointing (40-45 DAS)	69.40	8.6	11.5	40.13
T_3- 80 Kg ha^{-1} N (1/3rd basal, 2/3rd CRI – 80 Kg ha^{-1} N)	70.60	8.9	11.8	40.13
T_4- 80 Kg ha^{-1} N + one spray of NU (4 ml/litre) at tillering (30-35 DAS)	71.33	9.0	12.6	40.20
T_5- 80 Kg ha^{-1} N + two spray of NU (4 ml/litre) at tillering (30-35 DAS) and jointing (40-45 DAS)	73.20	9.1	12.6	40.23
T_6 - 80 Kg ha^{-1} N + one spray of urea (2%) at tillering (30-35 DAS)	75.00	9.2	13.5	40.23
T_7 - 80 Kg ha^{-1} N + two spray of urea (2%) at tillering (30-35 DAS) and jointing(40-45 DAS)	86.93	9.7	15.4	40.23
T_8 - 80 Kg ha^{-1} N + one spray of urea (2%) + NU (4 ml/litre) at tillering (30-35 DAS)	76.80	9.3	14.1	40.37
T_9 - 80 Kg ha^{-1} N + one spray of urea (2%) +DAP (2%) + NU (4 ml/litre) at tillering (30-35 DAS)	82.33	9.4	14.9	40.33
T_{10}- Control (Zero nitrogen)	64.93	8.4	10.0	40.10
SE (m) ±	2.49	0.70	0.45	0.11
CD	7.29	NS	1.30	NS

Significantly maximum grain yield (5098 kg ha^{-1}), cost of cultivation (37297 Rs. ha^{-1}), GMR (113826 Rs. ha^{-1}) and NMR (76529 Rs. ha^{-1}) and benefit: cost ratio (3.1) was recorded in the treatment T_7 - 80 Kg ha^{-1} N + two spray of urea (2%) at tillering (30-35 DAS) and jointing (40-45 DAS). Foliar application of nano-urea fertilizers significantly improved the dry matter accumulation. Increased leaf area aids in better solar radiation utilization and easily available nutrients which are vital for increasing photosynthetic surface area which might have resulted in more accumulation and translocation of photosynthates that eventually increased the dry matter production. Similar findings were reported by Rani *et al*. (2019) [13] in wheat. Valojai *et al*. (2021) [14] also found significantly higher yield with nano in combination with NPK in rice.

Table 2: Grain and straw yield, COC, GMR, NMR and B:C ratio of wheat as influence by various treatments.

Treatments	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	CoC (Rs ha^{-1})	GMR (Rs ha^{-1})	NMR (Rs ha^{-1})	B:C ratio
T_1- One spray of NU (4 ml/litre) at maximum tillering (30-35 DAS)	3467	3586	36235	77280	41046	2.1
T_2-Two spray of NU (4 ml/litre) at tillering (30-35 DAS) and jointing (40-45 DAS)	3480	3661	37945	77617	39672	2.1
T_3- 80 Kg ha^{-1} N (1/3rd basal, 2/3rd CRI – 80 Kg ha^{-1} N)	4388	4510	35690	97759	62070	2.7
T_4- 80 Kg ha^{-1} N + one spray of NU (4 ml/litre) at tillering (30-35 DAS)	4418	4536	37400	98423	61024	2.7
T_5- 80 Kg ha^{-1} N + two spray of NU (4 ml/litre) at tillering (30-35 DAS) and jointing (40-45 DAS)	4853	4874	39110	108008	68898	2.8
T_6 - 80 Kg ha^{-1} N + one spray of urea (2%) at tillering (30-35 DAS)	4893	5559	36493	109552	73059	3.0
T_7 - 80 Kg ha^{-1} N + two spray of urea (2%) at tillering (30-35 DAS) and jointing(40-45 DAS)	5098	5485	37297	113826	76529	3.1
T_8 - 80 Kg ha^{-1} N + one spray of urea (2%) + NU (4 ml/litre) at tillering (30-35 DAS)	4965	5302	37453	110814	73361	3.0
T_9 - 80 Kg ha^{-1} N + one spray of urea (2%) +DAP (2%) + NU (4 ml/litre) at tillering (30-35 DAS)	5036	5066	37723	112095	74371	3.0
T_{10}- Control (Zero nitrogen)	3265	3454	34525	72848	38323	2.1
SE (m) ±	467	515	-	10428	10428	-
CD	1367	1509	-	30512	30512	-

Significantly residual available nitrogen (192.64 kg ha^{-1}) and total nitrogen uptake (130.1 kg ha^{-1}) yield, NUE (73.48%), nitrogen (1.8%) and protein (10.26%) content was recorded in the treatment T_7 - 80 Kg ha^{-1} N + two spray of urea (2%) at tillering (30-35 DAS) and jointing(40-45 DAS). This may be due to the higher grain and straw yield obtained by the application of conventional urea fertilizers and later supported by nano urea foliar application. Deepa (2022) [4] reported similar finding that among the treatments, 100% RDN + 2 sprays of nano urea at tillering & jointing stages (T_{10}) which recorded maximum nitrogen use efficiency, net returns and B:C ratio. These findings are in conformation with the results of Meena *et al*. (2021) [7] and Bhattacharyya (2021) [3]. Thus, there was no any additional net return due to nitrogen application through nano urea application.

Table 3: Residual available nitrogen, total nitrogen uptake, nitrogen use efficiency, nitrogen and protein content in grain of wheat as influence by various treatments.

Treatments	Residual Ava. Nitrogen (kg ha^{-1})	Total Nitrogen uptake (kg ha^{-1})	Nitrogen use efficiency (%)	Nitrogen content in grain (%)	Protein content in grain (%)
T_1- One spray of NU (4 ml/litre) at maximum tillering (30-35 DAS)	185.05	68.95	-	1.4	7.98
T_2-Two spray of NU (4 ml/litre) at tillering (30-35 DAS) and jointing (40-45 DAS)	185.27	71.32	-	1.4	7.98
T_3- 80 Kg ha^{-1} N (1/3rd basal, 2/3rd CRI – 80 Kg ha^{-1} N)	185.27	94.19	28.58	1.5	8.55
T_4- 80 Kg ha^{-1} N + one spray of NU (4 ml/litre) at tillering (30-35 DAS)	185.68	95.24	29.90	1.5	8.55
T_5- 80 Kg ha^{-1} N + two spray of NU (4 ml/litre) at tillering (30-35 DAS) and jointing (40-45 DAS)	188.74	113.2	52.35	1.6	9.12
T_6 - 80 Kg ha^{-1} N + one spray of urea (2%) at tillering (30-35 DAS)	188.98	117.2	57.37	1.6	9.12
T_7 - 80 Kg ha^{-1} N + two spray of urea (2%) at tillering (30-35 DAS) and jointing(40-45 DAS)	192.64	130.1	73.48	1.8	10.26
T_8 - 80 Kg ha^{-1} N + one spray of urea (2%) + NU (4 ml/litre) at tillering (30-35 DAS)	189.80	119.3	60.00	1.7	9.69
T_9 - 80 Kg ha^{-1} N + one spray of urea (2%) +DAP (2%) + NU (4 ml/litre) at tillering (30-35 DAS)	190.67	122.07	63.43	1.7	9.69
T_{10}- Control (Zero nitrogen)	181.94	62.34	-	1.3	7.41
SE (m) ±	4.53	1.48	-	-	-
CD	NS	4.34	-	-	-

(Initial available N 191.40)

Application of recommended nitrogen with combination of 2% spray of urea at tillering and jointing recorded highest Growth parameter like plant height, number of tillers, dry matter production per plant and yield parameters like spike length, test weight, tillers per plant and yield per plant productivity which was at par with nano urea spray combinations. Application of recommended nitrogen with combination of 2% spray of urea at tillering and jointing stage recorded maximum gross and net monitory return of Rs. 113826 and 76529 ha^{-1}.

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