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Effect of foliar application of nano-urea on nutrient quality and yield of kharif rice (*Oryza sativa* L.) under lateritic soil condition

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Abstract
Appropriate nitrogen (N) management technique enhances nutritional properties and yield while limiting the environmental impact. In modern agriculture, precision nutritional management is led by nano-fertilizers. In this paper we investigate the "Effect of foliar application of Nano-Urea on nutrient quality and yield of kharif rice (*Oryza sativa* L.) under lateritic soil condition." A field experiment was conducted at Instructional Farm, Department of Agronomy, College of Agriculture, Dapoli; Dr. B. S. Konkan Krishi Vidyapeeth, Dapoli; during *Kharif*, 2022. The analytical work was done at research laboratory of Department of Agronomy. in randomized block design with 9 treatments *viz*., T_1: Control (no foliar application),T_2: 100% N, P_2O_5, K_2O RDF (Recommended Fertilizer Dose), T_3: 75% N + 100% P_2O_5 and K_2O + 1 spray of Nano-Urea @ 0.4% at 30 DAT, T_4: 75% N + 100% P_2O_5 and K_2O + 2 spray of Nano-Urea @ 0.4% at 30 and 50 DAT, T_5: 50% N + 100% P_2O_5 and K_2O + 2 spray of Nano-Urea @ 0.4% at 30 and 50 DAT, T_6: 50% N + 100% P_2O_5 and K_2O + 3 spray of Nano-Urea @ 0.4% at 30, 45 and 60 DAT, T_7: 25% N + 100% P_2O_5 and K_2O + 3 sprays of Nano-Urea @ 0.4% at 30, 45 and 60 DAT,T_8: 25% N + 100% P_2O_5 and K_2O + 4 sprays of Nano-Urea @ 0.4% at 15, 30, 45 and 60 DAT, and T_9: 100% P_2O_5 and K_2O + 4 sprays of Nano-Urea @ 0.4% at 15, 30, 45 and 60 DAT. replicated thrice. The results reveled that the maximum grain yield (4817.80 kg ha^{-1}), straw yield (5956.26 kg ha^{-1}) and biological yield (10774.06 kg ha^{-1}) of rice and higher nutrient (N, P and K) content and uptake by grain and straw and their total uptake by rice crop were also ensured under treatment receiving 50% N + 100% P_2O_5 and K_2O + 3 spray of nano-urea @ 0.4% at 30, 45 and 60 DAT (T_6).

Keywords: Nano-urea, rice, foliar application, nutritional properties, yield etc

1. Introduction
Cereal crops are among the oldest crops known to man, as they are the main source of food, and the most important of these crops is rice for its strategic role in ensuring food security. Approximately half of the world's population relies primarily on rice (*Oryza sativa* L.) for their food. It is generally considered a semi-aquatic annual grass plant. About 20 species of the genus *Oryza* are recognized, but nearly all cultivated rice is *O. sativa* L. cultivated over 165.25 million hectares with estimated production of 503.27 million metric tons around the globe in year (USDA, 2022).

India is the world's second-largest producer, and the largest exporter among top most rice producers of world after china. Rice is most significant crop in India where it is grown on an area of 43.90 million hectares, and contribute to 114.45 million tons production. (Anonymous, 2022a) [2]. In Maharashtra rice is second most important crop. The production scenario of Maharashtra reflected that rice occupies 15.55 lakh hectare area with total production of 34.81 lakh metric tone and average productivity 2.718 tonnes per hectare (Anonymous, 2022b) [2]. The konkan region is major rice producing area of Maharashtra. Around 3.56 lakh hectare area of konkan is under rice cultivation with rough rice production of 9.46 lakh tones. The average rice productivity of konkan region is 2652.21 kg per hectare (Anonymous, 2022 c).

This enhanced production is due to increased use of agricultural inputs like high yielding varieties of rice which are exceedingly responsive to fertilizers, among them nitrogen containing fertilizers are of paramount importance. The percentage of nitrogen absorbed by plants is significantly less than the amount of fertilizer applied, subsequently, farmers are obliged to add additional quantity of fertiliser to meet crops need (Kiran *et al*. 2021) [8]. Nitrogen use efficiency of rice crop under wetland conditions is very low, less than 30-35%. The major portion i.e., 65-70% of it is subjected to loss by leaching, vitalization and

denitrification processes (Manikandan *et al.* 2022) [13]. The major form of nitrogen ammonia, nitrate and amide are highly prone to these losses. Hence, it is critical to use modern technologies with smart delivery system, such as nano-fertilizers to increase the nitrogen use efficiency of fertilizers by reducing amount of conventional nitrogen fertilizer i.e., urea. Without affecting production and reducing the risks of environmental erosion on soil and water. To meet the urgent need of nitrogenous fertilizer that can increase the nutrient use efficiency, the practical application of Nano-technology in developing nano scaled nitrogen fertilizer are made. The word 'Nano' comes from Greek literature meaning dwarf, that is also one billionth part of meter 10^{-9}. The urea particles in nano size, called nano-urea. Nano urea is manufactured by scientist named Ramesh raliya at IFFCO – Indian Farmers Fertilizer Cooperative Limited by using spinning cone reactor and nano scale reactor, having particle size in range of 1-100 nm and 20-50 nm being finest and 4% nitrogen content by weight i.e., 40000 mg/l in each half litre bottle of nano-urea, which can curtail 50% conventional urea requirement and reduce 10% monetary value of the same. (Mansingh *et al.* 2023) [14]. Nano urea have several advantages, which includes reducing necessity of traditional urea by fifty percent (a bottle of half litre of liquid nano urea is analogue to one bag of 45 kg urea) thus, transportation would be more convenient and affordable (Baboo *et al*. 2021) [4]. Also capable of reducing greenhouse effect as it is biodegradable and lowers air and water pollution. More importantly, it is a less costly input that can reduce cost of crop production and boosts crop yield (Kumar *et al*. 2021) [24]. Nano urea also aids plants survival during drought conditions by lowering biotic and abiotic stress. It is environmentally safe since, it has potential to increase soil biomass, soil health and animal health. It is effective in increasing agronomic efficiency for nitrogen (AEN), crop recovery efficiency (CREN), which measures the amount of nutrient absorbed per unit nutrient applied in kilo grammes i.e., overall nitrogen use efficiency is enhanced by 3%. Because of its ultra-size, it has 10,000 times more surface area and penetrate more effectively through stomata and other parts of plant upon foliar spraying, these nano particles reach plant parts where nitrogen is required (Mansingh *et al*. 2023) [14]. And unused nitrogen is stored in vacuoles and nutrients are released in controlled manner. Resulting in better assimilation by plant cells subsequently high productivity of crop (Baboo *et al*. 2021) [4]. As a result, foliar feeding of nano-fertilizers remains the greatest alternative for increasing yield, nutrient usage efficiency and decreasing soil and environmental challenges while lowering reliance on soil chemical fertilizers, hence can be used as smart delivery system of nutrients to the plants.

2. Material and Method

2.1 Study area

Geographically, experimental plot (68) is situated in the subtropical region at 17°45'54" N latitude and 73°10'25" E longitude having elevation of about 292 m above mean sea level. The climate is sub-tropical which is characterized by warm and humid atmosphere.

The initial soil had pH of 6.24, EC of 0.119 dsm^{-1}, organic carbon of 11.70 g kg^{-1}, available nitrogen of 252.80 kg ha^{-1}, available phosphorous of 10.56 kg ha^{-1}, and available potassium of 228.63 kg ha^{-1}. Soil of experimental plot was sandy loam in texture, the main soil type was lateritic.

2.2 Experimental design and treatments

Layout of experiment was done as per the randomized block design. Taking 9 treatments with 3 replications all together there were 27 plots of 4.00 m × 4.50 m size in three replications. The treatment details along with their symbols which are frequently used in this experiment are mentioned in table 1.

Table 1: Treatment details along with the symbols used

Treatments	Symbols used
Control.	T_1
100% N, P_2O_5, K_2O RDF (Recommended Fertilizer Dose)	T_2
75% N + 100% P_2O_5 and K_2O + 1 spray of Nano-Urea @ 0.4% at 30 DAT.	T_3
75% N + 100% P_2O_5 and K_2O + 2 spray of Nano-Urea @ 0.4% at 30 and 50 DAT.	T_4
50% N + 100% P_2O_5 and K_2O + 2 spray of Nano-Urea @ 0.4% at 30 and 50 DAT.	T_5
50% N + 100% P_2O_5 and K_2O + 3 spray of Nano-Urea @ 0.4% at 30, 45 and 60 DAT.	T_6
25% N + 100% P_2O_5 and K_2O + 3 sprays of Nano-Urea @ 0.4% at 30, 45 and 60 DAT.	T_7
25% N + 100% P_2O_5 and K_2O + 4 sprays of Nano-Urea @ 0.4% at 15, 30, 45 and 60 DAT.	T_8
100% P_2O_5 and K_2O + 4 sprays of Nano-Urea @ 0.4% at 15, 30, 45 and 60 DAT.	T_9

The dose of N: P_2O_5: K_2O was applied to rice crop as per the requirement of treatments in the form of Urea, single super phosphate and Muriate of Potash, respectively. The application of full dose of phosphorous and potassium and 40% dose of nitrogen from conventional urea were applied as basal at the time of transplanting, remaining 40% at the time of maximum tillering stage and remaining 20% at flowering stage. The foliar application of Nano-Urea is given at 15, 30, 45, 50, 60 DAT to different plots as per treatment details described in Table 3.5. The spraying was done by using knapsack sprayer of 16 litres capacity and water used for spraying was clean and salt free.

3. Results and Discussion

3.1 Yield parameters and yield

Results depicated in Table 2. Shows that the foliar application of nano-urea significantly increased yield attributes except 1000 grain weight. Significantly higher yield attributing characters such as number of panicles $hill^{-1}$ (10.30), panicle length (22.37cm), total number of grains $panicle^{-1}$ (173.87), weight of panicle (2.82 g) was recorded under treatment T_6 receiving 50% RDN applied through conventional urea in 3 split doses (40:40:20) along with 3 foliar sprays of nano-urea at 30,45 and 60 DAT. This might be as a result of foliar application of nano-urea at critically growth stages of rice

increased the availability of nitrogen to crops, which further augment the cell elongation, activity of merismatic cells as well as increase grain formation (Sahu *et al.*, 2022) [18] also, the synergetic effect of nano nitrogen through foliar penetration of nutrients and conventional urea through roots uptake that improved nitrogen uptake by the plant leading to improved photosynthesis, thus resulting in increased source and sink capacity (Taiz and Zeiger, 2006) [23].

Table 2: Yield contributing characters of rice as influenced by different treatments

Treat.	No. of panicles hill^{-1}	No. of grains panicle^{-1}	Panicle length (cm)	Weight of panicle (g)	1000 grain weight (g)	Grain yield (kg ha $^{-1}$)	Straw yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
T_1	6.80	130.50	18.50	1.33	12.20	2950.54	3746.33	6696.87	44.06
T_2	8.27	152.60	19.73	1.97	13.06	4181.48	5240.53	9422.01	44.38
T_3	8.33	157.00	20.27	2.08	13.23	4491.79	5604.38	10096.17	44.49
T_4	9.75	163.43	20.87	2.29	13.31	4659.67	5780.07	10439.73	44.63
T_5	9.87	166.97	21.73	2.34	13.32	4710.53	5843.39	10553.92	44.63
T_6	10.30	173.87	22.37	2.82	13.35	4817.80	5956.26	10774.06	44.72
T_7	7.73	144.67	19.20	1.70	12.76	4035.87	5068.21	9104.08	44.33
T_8	7.93	144.90	19.67	1.80	12.65	4054.91	5085.98	9140.89	44.36
T_9	7.27	138.83	18.87	1.60	12.39	3984.13	5019.52	9003.65	44.25
S.Em. (±)	0.29	3.55	0.32	0.21	0.33	16.05	18.41	20.05	-
C.D. at 5%	0.88	10.64	0.97	0.63	NS	48.13	55.18	60.12	-

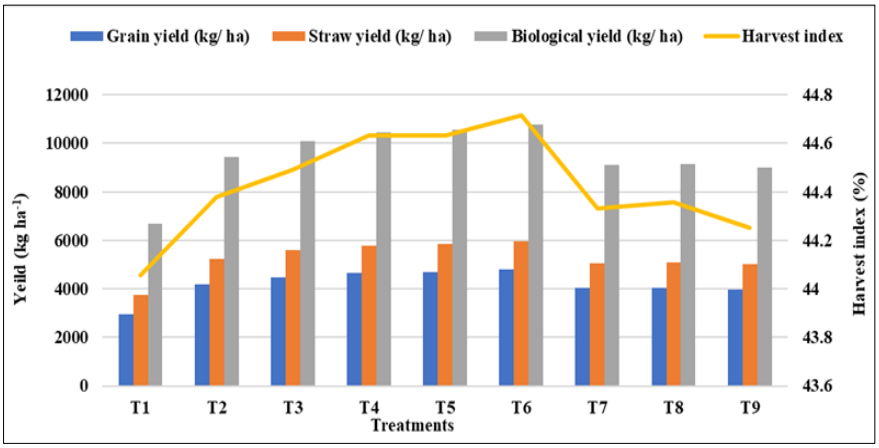

Fig 1: Grain yield, straw yield, biological yield (kg ha^{-1}) and harvest index (%) of rice as influenced by different treatments

These results showed strong agreement with findings of Rawate *et al.* (2022) [16], Mehta and Bharat (2019) [15]. Application of nano-urea fertilizer had significant impact on yield of rice, among the applied treatments, T_6 (50% N + 3 spray of Nano-
Urea @ 0.4% at 30, 45 and 60 DAT) recorded significantly higher grain yield (4817.80 kg ha^{-1}), straw yield (5956.26 kg ha^{-1}), biological yield (10774.06 kg ha^{-1}) and harvest index (44.72%). While, control treatment with no fertilizer application recorded least grain, straw and biological yield and harvest index. This increment in yield is might be due to, foliar application of nano-urea fertilizer boosts fast uptake by the plant and ease the translocation resulting in increased yield by promoting metabolic processes like photosynthesis and growth of plant parts and that cause more photosynthates to accumulate and translocate to economic parts of plant hence ensuring higher yield as stated by Apoorva *et al.*, (2017) [25], Mehta and Bharat (2019) [15], Algym *et al.* (2020) [1] and Sahu *et al.* (2022) [18]. Current research findings are in line with Lahari *et al.* (2021) [11], Kumar *et al.* (2020) [26], Khalil *et al.* (2019) [7], Sahu *et al.* (2022) [18] Yadav *et.al.* (2021) [24], Tarafdar *et al.* (2012) [27], Sirisena *et al.* (2013) [20], and Kumar *et al.* (2014) [9].

3.2 Nutrient uptake and content

Among the various nano-urea fertility levels, there was significant improvement in nutrient content and uptake with application of 50% N + 100% P_2O_5 and K_2O + 3 foliar sprays of nano-urea @ 0.4% at 30, 45 and 60 DAT (T_6) which recorded highest content of nitrogen (grain 1.276%, straw 0.557%), phosphorous (grain 0.342%, straw 0.210%) as well as potassium (grain 0.387, straw 1.179%), respectively. However, the uptake of nitrogen (grain 61.46 kg ha^{-1}, straw 33.16 kg ha^{-1}), phosphorous (grain 16.49 kg ha^{-1}, straw 12.50 kg ha^{-1}) as well as potassium (grain 18.63 kg ha^{-1}, straw 70.22 kg ha^{-1}) also recorded similar trend. Total uptake of nitrogen (94.61 kg ha^{-1}), phosphorous (29.00 kg ha^{-1}), and potassium (88.85 kg ha^{-1}), also recorded significantly higher with application of 50% N + 100% P_2O_5 and K_2O + 3 foliar sprays of Nano-Urea @ 0.4% at 30, 45 and 60 DAT (T_6), while, the lowest nutrient content and uptake was recorded in control treatment with no fertilizer application.

The nutrient levels in crop were found to be augmented because of, larger surface area and nano scale particle size and increased number of particles per unit area of nano-fertilizer, which effectively enters through the stomatal openings of leaves and increase the nutrient use efficiency and nutrient uptake, thus results in higher nutrient content in crop (Liscano *et al.* 2000) [12]. Significant improvement in the present study is in close association with Yadav *et.al.* (2021) [24], Rizwan *et al.* (2021) [17], Javed *et al.* (2019) [6] Bora and Pandey (2018) [28], Sahu *et al.* (2022) [18], Sharma *et al.* (2022) [11], Mehata and Bharat. (2019) [15], Burhan and AL-Hassan (2019) [5] and Lahari *et al* [11].

Table 3: N, P and k content in grain and straw and its total uptake (kg ha-1) by rice crop as influenced by different treatments

Treat.	N content (%)		Total N uptake (kg ha$^{-1)}$	P content (%)		Total P uptake (kg ha$^{-1)}$	K content (%)		Total K uptake (kg ha$^{-1)}$
	Grain	Straw		Grain	Straw		Grain	Straw	
T_1	1.000	0.284	40.145	0.203	0.148	11.542	0.292	1.108	50.137
T_2	1.228	0.513	78.237	0.301	0.182	22.111	0.337	1.139	73.751
T_3	1.231	0.523	84.639	0.325	0.193	25.400	0.366	1.151	80.950
T_4	1.254	0.530	89.087	0.329	0.202	26.971	0.372	1.166	84.695
T_5	1.255	0.534	90.341	0.334	0.205	27.690	0.374	1.168	85.884
T_6	1.276	0.557	94.615	0.342	0.210	29.001	0.387	1.179	88.853
T_7	1.217	0.503	74.614	0.272	0.172	19.665	0.329	1.132	70.637
T_8	1.223	0.510	75.537	0.278	0.177	20.275	0.333	1.136	71.310
T_9	1.197	0.493	72.442	0.240	0.166	17.864	0.312	1.120	68.656
S.Em. (±)	0.005	0.003	0.329	0.007	0.003	0.271	0.004	0.003	0.403
C.D. at 5%	0.015	0.010	0.985	0.021	0.008	0.814	0.011	0.009	1.209

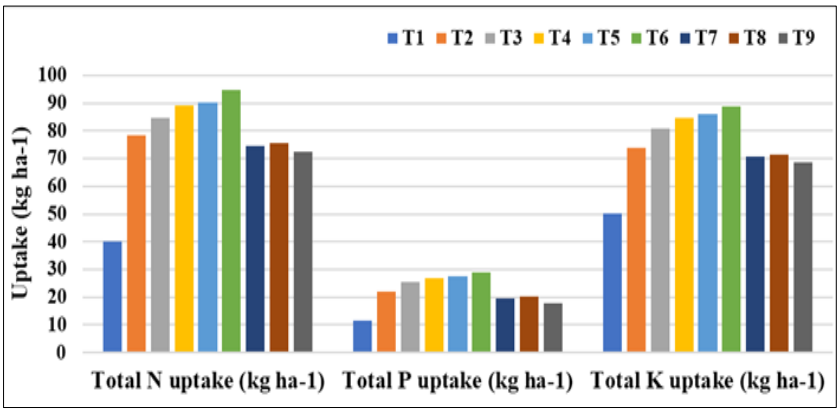

Fig 2: Total N, P and K uptake (kg ha^{-1}) by rice crop as influenced by different treatments

4. Conclusion

It could be concluded that, the higher yield attributes as well as grain, straw and biological yield from kharif rice could be obtained by application of 50% N + 100% P_2O_5 and K_2O + 3 foliar sprays of Nano-Urea @ 0.4% at 30, 45 and 60 DAT. In addition, it also improves nutritional composition of grain and straw.

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