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Effect of nano-fertilizers on physico-chemical properties of soil in transplanted hybrid rice (*Oryza sativa* L.)

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Abstract

Experiment was conducted during *Kharif* season of 2022 and 2023 at Students' Instructional Farm, Department of Agronomy, Chandra Shekhar Azad University of Agriculture & Technology, Kanpur-208002 (U.P.) India, using different combinations of nano-urea and nano-zinc fertilizers under rice cultivation. The experiment was laid out in Randomized Block Design with thirteen treatments each replicated thrice. The results showed that the application of nano-fertilizers did not significantly alter bulk density, which ranged from 1.39 to 1.42 Mg m³, or particle density, which remained between 2.70 and 2.72 Mg m³ across treatments. Soil pH exhibited minimal variation, from 7.79 to 7.96, while electrical conductivity ranged between 0.31 to 0.37 dSm⁻¹. Organic carbon content was consistent across treatments, ranging from 0.31% to 0.36%. In terms of nutrient availability, the highest nitrogen content (191.98 kg ha⁻¹) was recorded in the treatment combining 100% RDN with nano-urea and nano-zinc (T₁₃), while control treatments showed lower levels (172.60 kg ha⁻¹). Phosphorus, potassium, and zinc availability also improved slightly under nano-fertilizer treatments, with maximum values of 12.92 kg ha⁻¹ (P), 153.92 kg ha⁻¹ (K), and 0.64 mg kg⁻¹ (Zn). In conclusion, the use of nano-fertilizers, specifically nano-urea and nano-zinc, holds potential for improving soil health and ensuring sustainable rice production by maintaining soil nutrient balance and supporting microbial activity. The findings suggest that nano-fertilizers are a viable strategy for enhancing both crop yield and soil sustainability. Nano-fertilizers offer an innovative approach to sustainable farming by providing controlled nutrient release, improving uptake efficiency, and reducing nutrient loss.

Keywords: Nano-fertilizers, rice cultivation, soil health, nutrient and sustainability

1. Introduction

Rice (*Oryza sativa* L.) comes under the family "*Poaceae*" and genus "*Oryza*". It is a tropical climate with *Kharif* season crop, hot and humid climate being very favourable for its growth and maturity (Gopala *et al.*, 2022) [6]. Globally around 165.68 million hectares area is under rice along with 514.57 million tones production and 4.64 MT ha⁻¹ productivity during 2022-23. In India around 47.83 million hectares area is under rice along with 135.76 million tones production and 4.26 MT ha⁻¹ productivity in 2022-23. The production of rice in Uttar Pradesh is 15.96 million tones and productivity of rice is 2673 kg ha⁻¹. Total area under rice cultivation in Uttar Pradesh is 5.97 million hectares.

Chemical fertilizers have been considered an essential component of contemporary agricultural production methods since the green revolution, but they also have linked environmental and ecological effects. Since the start of the green revolution, intensive agricultural methods have developed and been found to be unsustainable due to the utilization efficacy of applied chemicals, especially mineral fertilizers, remaining below 30% (John and Babu, 2021) [11]. A growing worry is the loss of mineral nutrients through leaching and runoff to surface and ground water, as well as the extensive volatilization that results from lost revenue and environmental damage (Huang *et al.*, 2017) [9].

About 35–40% of crop output in India comes from rice, which is mostly dependent on the prudent use of fertilizers as inputs.

The use of inorganic fertilisers indiscriminately and unevenly has a negative impact on soil health, which lowers soil productivity. Because of leaching, volatilization, and denitrification losses that contribute to the emission of greenhouse gases, it has been discovered that the application of inorganic fertilisers, such as urea, DAP, and MOP, has lower fertiliser use efficiency in rice crops. (Chinnamuthu and Boopathi, 2017) ^[2]. Nanotechnology shows promise in addressing these issues, and nano-fertilizers offer a means of guaranteeing long-term soil health and increased crop yields (Lal, 2008) ^[15]. Crop productivity, quality, and the general sustainability of agricultural systems can all be improved by using nano-fertilizers, which deliver nutrients to the crop gradually and steadily as needed (Tarafdaret *al.* 2014) ^[28]. For effective nutrient control, nanoparticles smaller than 100 nm can be utilized as micro fertilizer.

Nano fertilisers are environmentally friendly, made using a biological method, and have been engineered to be comparable to inorganic fertilisers in terms of nutrient content and rate of application. In order to control nutrient release more effectively than conventional fertilisers, nano fertilisers are created (Liu and Lal, 2015) ^[17]. Consequently, the use of nano fertilisers appears to be a viable way to guarantee effective nutrient translocation to the necessary sections of plants.

Unlike conventional fertilizers, nano fertilizers provide a controlled release of nutrients, leading to more efficient uptake

by plants and minimizing nutrient losses through leaching and volatilization. This efficient nutrient management not only enhances crop productivity but also influences post-harvest soil properties. Studies have shown that nano urea and nano zinc can positively affect soil health by maintaining soil nutrient balance and enhancing microbial activity (Meena *et al.*, 2020) ^[18]. Improved soil properties post-harvest contribute to sustainable agricultural practices by preserving soil fertility and structure, reducing the need for excessive fertilizer inputs in subsequent cropping cycles. The adoption of nano fertilizers, therefore, offers a promising strategy for enhancing soil health and promoting sustainable rice cultivation.

2. Method and Materials

2.1 Experimental Location

The experiment was conducted at “Student’s Instructional Farm” of Chandra Shekhar Azad University of Agriculture & Technology, Kanpur- 208002 (U.P.) which is situated in the alluvial tract of Indo-Gangatic plain in central part of Uttar Pradesh between 25°26' to 26°58' North latitude, 79°31' to 31°34' East longitude and on the altitude of 125.9 meters.

2.2 Soil characteristics

Before setting up the experiment, random five spots were chosen from site of experiment to gather composite soil samples ranging in depth from 0 to 15 cm.

Table 1: Soil properties of the experimental site

Sr. No.	Particulars	Experimental value		Methods employed
		2022	2023	
A.	Physical properties			
i.	Sand (%)	24.86	24.86	Hydro meter method
ii.	Silt (%)	53.94	53.94	
iii.	Clay (%)	21.20	21.20	
iv.	Textural class	Sandy loam	Sandy loam	Triangular method
v.	Bulk density(gcm ⁻³)	1.38	1.38	Core sampler method
B.	Chemical properties			
i.	Soil reaction pH (1:2.5) soil: water suspension	7.71	7.68	Glass electrode pH meter
ii.	Organic carbon (%)	0.38	0.45	Walkley and Black’s Rapid titration method (Walkley & Black, 1934) ^[29]
iii.	Electricalconductivity (dSm ⁻¹)	0.35	0.38	Electrical conductivity bridge meter (Richards, 1954) ^[24]
iv.	Available N (kg ha ⁻¹)	172.50	180.32	Alkaline permanganate method (Subbiah and Asija, 1956) ^[26]
v.	Available P (kg ha ⁻¹)	11.00	12.00	Olsen’s calorimetrically method (Olsen <i>et al.</i> , 1954) ^[20]
vi.	Available K ₂ O (kg ha ⁻¹)	156.40	158.30	Flame photometer (Hanwey and Heidel, 1952) ^[8]
vii.	Available Zinc (mg kg ⁻¹)	0.547	0.562	DTPA Extraction method Lindsevand Norvell (1978) ^[16]

2.3 Treatment Details

Table 2: Details of the treatments

Symbol	Treatment Combinations
T ₁	Control
T ₂	50% RDN
T ₃	50% RDN + Nano Urea
T ₄	75% RDN
T ₅	75% RDN + Nano Urea
T ₆	100% RDN
T ₇	100% RDN + Nano Urea
T ₈	50% RDN + NanoZinc
T ₉	50% RDN + NanoUrea + NanoZinc
T ₁₀	75% RDN + NanoZinc
T ₁₁	75% RDN + NanoUrea + NanoZinc
T ₁₂	100% RDN + NanoZinc
T ₁₃	100% RDN + NanoUrea + NanoZinc

Recommended dose of fertilizer was 150: 60: 60:: N: P₂O₅: K₂O,

respectively; The Urea, DAP and MOP was used as a source of N, P and K. full P and K were applied as basal; Urea was applied into equal-split at basal, active - tillering and panicle initiation stage.

2.4 Statistical analysis

The data obtained from different observation was subjected to statistical analysis as per Randomize Block Design by Standard Method suggested by Fisher and Yates (1963) ^[5].

3. Results and Discussion

3.1 Physical property of soil (Bulk density and Particle density)

The data related to bulk density and particle density of soil depicted in Table-3. The pooled data from 2022 and 2023 for soil physical properties, specifically bulk density and particle density, revealed non-significant differences across all treatments. Bulk density values were relatively stable, ranging

from 1.39 Mg m⁻³ in treatments like T₄-75% RDN, T₇ - 100% RDN + Nano Urea, and T₁₂ - 100% RDN + Nano Zinc to 1.42 Mg m⁻³ in treatments like T₅- 75% RDN + Nano Urea and T₈ - 50% RDN + Nano Zinc. T₁ - Control had a pooled bulk density of 1.41 Mg m⁻³. Similarly, particle density across treatments showed minimal variation, with all treatments recording values

around 2.70 to 2.72 Mg m⁻³. T₁ - Control had a pooled particle density of 2.71 Mg m⁻³, which was closely matched by all other treatments, including T₁₃- 100% RDN + Nano Urea + Nano Zinc with 2.71 Mg m⁻³ and T₁₂ - 100% RDN + Nano Zinc with 2.72 Mg m⁻³. These results are in line with finding of Subramanian & Thirunavukkarasu (2017)^[27], Saran *et al.* (2024)^[24].

Table 3: Effect of different treatment combinations on post-harvest physical properties of soil

Treatments	Bulk density (Mgm ⁻³)			Particle density (Mgm ⁻³)		
	2022	2023	Pooled	2022	2023	Pooled
T ₁ - Control	1.41	1.40	1.41	2.70	2.71	2.71
T ₂ -50% RDN	1.40	1.41	1.41	2.71	2.69	2.70
T ₃ -50% RDN+ Nano Urea	1.40	1.40	1.40	2.71	2.70	2.71
T ₄ -75% RDN	1.39	1.39	1.39	2.70	2.70	2.70
T ₅ -75%RDN+Nano Urea	1.42	1.41	1.42	2.70	2.70	2.70
T ₆ -100% RDN	1.41	1.39	1.40	2.72	2.71	2.72
T ₇ -100%RDN+Nano Urea	1.39	1.40	1.40	2.71	2.70	2.71
T ₈ -50%RDN+NanoZinc	1.42	1.42	1.42	2.71	2.71	2.71
T ₉ -50%RDN+NanoUrea+ Nano Zinc	1.41	1.40	1.41	2.70	2.69	2.70
T ₁₀ -75%RDN+NanoZinc	1.42	1.41	1.42	2.70	2.70	2.70
T ₁₁ -75%RDN+NanoUrea+ Nano Zinc	1.40	1.40	1.40	2.72	2.71	2.72
T ₁₂ -100%RDN+NanoZinc	1.39	1.39	1.39	2.72	2.72	2.72
T ₁₃ -100%RDN+NanoUrea +Nano Zinc	1.40	1.41	1.41	2.71	2.70	2.71
SE(d)±	0.06	0.07	0.07	0.141	0.140	0.140
C.D at 5%	NS	NS	NS	NS	NS	NS

3.2 Chemical property of soil (Organic carbon, pH and EC)

The data related to organic carbon, pH and EC of soil presented in Table-4. The pooled data from 2022 and 2023 for soil chemical properties, specifically organic carbon (OC), pH, and electrical conductivity (EC), showed non-significant differences across all treatments. Organic carbon content in the soil remained largely consistent, with values ranging from 0.31% in T₁₁- 75% RDN + Nano Urea + Nano Zinc to 0.36% in treatments like T₄- 75% RDN and T₇ - 100% RDN + Nano Urea. The control treatment, T₁, had OC content of 0.35%, which was on par with most other treatments. Similarly, soil pH showed minimal variation across the treatments. T₁ - Control exhibited a

pH of 7.96, which was very close to other treatments, such as T₃- 50% RDN + Nano Urea with a pH of 7.96 and T₁₃ - 100% RDN + Nano Urea + Nano Zinc with a slightly lower pH of 7.80. For electrical conductivity (EC), the data revealed non-significant differences between treatments. T₁- Control had minimum EC of 0.31 dS m⁻¹, while the highest EC was recorded in T₁₃ - 100% RDN + Nano Urea + Nano Zinc at 0.37 dS m⁻¹. Other treatments, such as T₇- 100% RDN + Nano Urea and T₁₂- 100% RDN + Nano Zinc, also had slightly elevated EC values of 0.35 dS m⁻¹. These results are in accordance with the findings of El-Sharkawy *et al.*, (2021)^[4], Kumar *et al.*, (2024)^[14] and Sharma *et al.*, (2024)^[25].

Table 4: Effect of different treatment combinations on post-harvest chemical properties of soil

Treatments	Organic carbon (%)			pH			EC (dSm ⁻¹)		
	2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled
T ₁ - Control	0.35	0.34	0.35	7.96	7.95	7.96	0.31	0.30	0.31
T ₂ -50% RDN	0.34	0.36	0.35	7.97	7.97	7.97	0.32	0.31	0.32
T ₃ -50%RDN+ Nano Urea	0.35	0.34	0.35	7.96	7.95	7.96	0.34	0.33	0.34
T ₄ -75% RDN	0.36	0.36	0.36	7.95	7.95	7.95	0.32	0.31	0.32
T ₅ -75%RDN+Nano Urea	0.34	0.35	0.35	7.96	7.96	7.96	0.34	0.33	0.34
T ₆ -100% RDN	0.35	0.36	0.36	7.93	7.92	7.93	0.32	0.31	0.32
T ₇ -100%RDN+Nano Urea	0.36	0.36	0.36	7.91	7.90	7.91	0.35	0.34	0.35
T ₈ -50%RDN+NanoZinc	0.32	0.33	0.33	7.89	7.90	7.90	0.33	0.31	0.32
T ₉ -50%RDN+NanoUrea+ Nano Zinc	0.33	0.34	0.34	7.92	7.91	7.92	0.34	0.33	0.34
T ₁₀ -75%RDN+NanoZinc	0.32	0.32	0.32	7.88	7.87	7.88	0.33	0.32	0.33
T ₁₁ -75%RDN+NanoUrea+ Nano Zinc	0.31	0.33	0.32	7.84	7.83	7.84	0.36	0.35	0.36
T ₁₂ -100%RDN+NanoZinc	0.33	0.31	0.32	7.82	7.80	7.81	0.35	0.34	0.35
T ₁₃ -100%RDN+NanoUrea +Nano Zinc	0.32	0.32	0.32	7.79	7.80	7.80	0.37	0.36	0.37
SE(d)±	0.018	0.017	0.019	0.408	0.407	0.407	0.018	0.017	0.018
C.D at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS

3.3: N P K and Zn content in soil

The data pertaining to N P K and Zn content in soil are presented in Table-5. Nitrogen availability in the soil showed minimum variations; with T₁- Control having 172.60 kg ha⁻¹ and T₁₃- 100% RDN + Nano Urea + Nano Zinc reaching the highest value 191.98 kg ha⁻¹. However, these differences were statistically non-significant, indicating that even higher doses of

RDN with Nano Urea and Nano Zinc did not drastically alter the residual nitrogen content in the soil compared to the control. Similar results were found by Rohitha *et al.* (2024)^[22].

The effect of nano fertilizers on availability of phosphorus was showed non-significance difference between all of treatments. Numerically, maximum P 12.92 kg ha⁻¹ was recorded under - 100% RDN + Nano Urea + Nano Zinc (T₁₃) treatment, however,

the minimum P availability recorded with control treatment in transplanted hybrid rice during both of year as well as pooled basis. These results are in confirmation with finding of Kumar and Dahiya (2024) ^[14].

In case of potassium availability, the results again showed non-significant variations. T₁₃- 100% RDN + Nano Urea + Nano Zinc was observed maximum K (153.92 kg ha⁻¹) and minimum under Control (138.57 kg ha⁻¹) in transplanted hybrid rice. Similar results were found by Nandy *et al.*, (2023) ^[19].

The effect of various nano fertilizers treatments on availability of zinc was resulted non-significance difference. Numerically, highest Zn (0.63 mg kg⁻¹) was recorded under - 100% RDN + Nano Urea + Nano Zinc (T₁₃) treatment and the minimum Zn availability (0.60 mg kg⁻¹) recorded under control treatment in transplanted hybrid rice during both of year as well as pooled basis. These results are in confirmation with finding of Khardia *et al.*, (2022) ^[12].

Table 5: Effect of different treatment combinations on fertility of soil

Treatments	Available N (kg ha ⁻¹)			Available P (kg ha ⁻¹)			Available K (kg ha ⁻¹)			Available Zn (mg kg ⁻¹)		
	2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled
T ₁ - Control	170.98	174.22	172.60	11.25	11.45	11.35	137.12	140.03	138.57	0.59	0.60	0.60
T ₂ -50% RDN	172.82	176.30	174.56	12.32	12.54	12.43	142.10	145.01	143.56	0.60	0.61	0.61
T ₃ -50%RDN+ Nano Urea	176.35	179.70	178.02	12.53	12.76	12.64	145.67	148.76	147.21	0.60	0.61	0.61
T ₄ -75% RDN	178.39	181.92	180.15	12.58	12.83	12.70	146.35	149.42	147.89	0.60	0.62	0.61
T ₅ -75%RDN+Nano Urea	184.62	188.33	186.48	12.68	12.94	12.81	148.98	152.14	150.56	0.60	0.61	0.61
T ₆ -100% RDN	181.82	185.28	183.55	12.65	12.90	12.78	146.74	149.82	148.28	0.61	0.62	0.62
T ₇ -100%RDN+Nano Urea	187.32	191.09	189.20	12.75	13.01	12.88	150.56	153.72	152.14	0.61	0.62	0.62
T ₈ -50%RDN+NanoZinc	174.65	178.14	176.40	12.46	12.71	12.58	144.86	147.93	146.40	0.61	0.62	0.62
T ₉ -50%RDN+NanoUrea+ Nano Zinc	185.63	189.36	187.50	12.70	12.94	12.82	149.23	152.39	150.81	0.62	0.63	0.63
T ₁₀ -75%RDN+NanoZinc	183.24	186.83	185.03	12.62	12.87	12.74	147.24	150.30	148.77	0.62	0.63	0.63
T ₁₁ -75%RDN+NanoUrea+ Nano Zinc	188.65	192.45	190.55	12.78	13.04	12.91	151.98	155.20	153.59	0.62	0.63	0.63
T ₁₂ -100%RDN+NanoZinc	186.79	190.45	188.62	12.73	12.98	12.86	149.65	152.72	151.19	0.62	0.63	0.63
T ₁₃ -100%RDN+NanoUrea +Nano Zinc	190.12	193.85	191.98	12.80	13.04	12.92	152.32	155.53	153.92	0.62	0.64	0.63
SE(d)±	9.43	9.62	9.52	0.65	0.66	0.66	7.63	7.79	7.71	0.03	0.03	0.03
C.D at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

4. Conclusion

This study highlights the positive impact of nano-fertilizers on soil health and nutrient management in rice cultivation. The application of nano-urea and nano-zinc showed a potential for enhancing the availability of key nutrients like nitrogen, phosphorus, potassium, and zinc while maintaining stable soil physical properties. These improvements suggest that nano-fertilizers can be an effective strategy for promoting sustainable agricultural practices by reducing nutrient losses and enhancing fertilizer use efficiency.

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