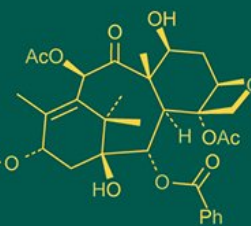
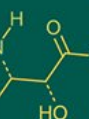
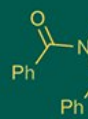


International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2026): 5.29
IJABR 2026; SP-10(9): 380-384
www.biochemjournal.com
Received: 07-07-2026
Accepted: 12-08-2026

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Studies on the effect of nano-nitrogenous fertilizer on growth of rice crop (*Oryza sativa* L.)

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DOI: <https://www.doi.org/10.33545/26174693.2026.v10.i9Se.9856>

Abstract

A field experiment was conducted during *Kharif* season of 2025 on the topic entitled “Studies on the effect of nano-nitrogenous fertilizer on growth, yield and quality of rice crop (*Oryza sativa* L.)” in sandy loam soil of SIF, Rama University, Kanpur (U.P.). The experiment was laid out in Randomized Block design with three replications and Nine treatments viz- T₁- Control (100% P & K), T₂- 100% RDN & 100% P & K, T₃-75%N RDN & 100% P & K, T₄- T₂ + Nano N Spray at 30 DAT, T₅- T₂ + Nano N Spray at 45 DAT, T₆- T₂ + Nano N Spray at 30 & 45 DAT, T₇-T₃ + Nano N Spray at 30 DAT, T₈- T₃ + Nano N Spray at 45 DAT and T₉- T₃ + Nano N Spray at 30 & 45 DAT. Higher growth attributing characters at different crop stages viz. plant height, dry matter accumulation, No. of tillers m⁻², & were produced in rice with T₆- T₂ + Nano N Spray at 30 & 45 DAT treatment.

Keywords: Rice, *Oryza sativa* L., nano-nitrogenous fertilizer, nano nitrogen, nitrogen management, growth, yield, quality, randomized block design

Introduction

Rice (*Oryza sativa* L.) is the primary food source for more than half of the world's population and plays a vital role in global food security. In India, it is one of the most important cereal crops with respect to cultivated area, total production, and productivity. Globally, rice is cultivated over nearly 162 million hectares with an annual production of about 503 million tonnes and an average productivity of around 4.67 t ha⁻¹. In Southeast Asia, the average productivity is approximately 4.41 t ha⁻¹ (FAOSTAT, 2020) [6]. In India, rice contributes significantly to total food grain and cereal production. The crop occupies about 44 million hectares with production exceeding 120 million tonnes, while productivity ranges around 2.8 t ha⁻¹. During 2022-23, the country's rice production was estimated at nearly 125 million tonnes. (Anonymous 2022-23). An average productivity of 2.6 t/ha (NRRI, 2020). It is thus no surprise that India had the highest export volume of rice worldwide, at 21.5 million metric tons as 2022-23 (APEDA, Ministry of commerce and industry, Govt. of India).

Agriculture in Uttar Pradesh is highly diversified due to its wide agro-climatic variability, which supports the cultivation of several crops. Among food grains, rice is one of the most important crops in the state. Uttar Pradesh is the second largest rice-producing state in India after West Bengal. Rice is cultivated over about 5.8 million hectares in the state with an annual production of nearly 15.27 million tonnes, contributing around 12% to the total rice production of the country. (Economic Survey 2022-23).

Rice serves as the staple food for nearly half of the global population and provides a major share of daily calorie and protein intake, especially in developing countries. Rice grains mainly consist of carbohydrates in the form of starch, along with moderate amounts of protein, moisture, and small quantities of fat. Because of its nutritional importance and widespread consumption, improving rice productivity remains essential for ensuring food security (Sangeetha and Baskar).

Fertilizers play a vital role in enhancing crop growth and productivity. Since the introduction of high-yielding fertilizer-responsive varieties during the Green Revolution, fertilizer consumption in Indian agriculture has increased considerably.

However, excessive and imbalanced use of fertilizers, particularly nitrogenous fertilizers such as urea, has created several challenges including low nutrient use efficiency, micronutrient deficiencies, groundwater contamination, and eutrophication of water bodies. In cereals, the recommended N:P:K ratio is generally 4:2:1, but the current imbalance in fertilizer application has widened considerably due to the overuse of nitrogen fertilizers.

Most rice-growing soils are deficient in nitrogen, and only a limited amount of the crop's nitrogen requirement is fulfilled through biological nitrogen fixation by cyanobacteria and other diazotrophic microorganisms (Hashem). Therefore, application of nitrogen fertilizer becomes essential to meet the nutrient requirement of the rice crop. However, the efficiency of applied nitrogen in rice largely depends on the source, method and rate of application, as well as crop and nutrient management practices. (Wang *et al.*, 2011) [19]. Prilled urea (PU) is commonly used as a nitrogen source in rice cultivation, but its nitrogen use efficiency is relatively low, generally ranging between 30-45%. Major nitrogen losses occur through denitrification, ammonia volatilization, and leaching, which reduce the effective utilization of applied nitrogen by the crop (Hakeem *et al.*, 2011) [8]. Therefore, the development of slow-release fertilizers is necessary to regulate nitrification and ensure a continuous supply of nitrogen throughout the crop growth period. Nitrogen is an essential nutrient for all crops and is particularly important in cereal crops due to its major role in plant growth, development, and grain production (Sahrawat, 2000) [18]. Currently, nitrogen fertilizer is used to produce food for half of the world's population (Ladha *et al.*, 2005) [11].

Among all essential nutrients, nitrogen plays the most significant role in rice growth and productivity. Adequate nitrogen availability during tillering, panicle initiation, and grain filling stages is essential for proper crop development and higher grain yield. In puddled rice ecosystems, nearly 60% of the applied nitrogen may be lost through different pathways, resulting in poor nitrogen use efficiency. With the expansion of high-yielding rice varieties, nitrogen fertilizer application has increased substantially in many countries. Rice cultivation alone accounts for a considerable share of global nitrogen fertilizer consumption. However, excessive and imbalanced use of nitrogen fertilizers often leads to nutrient losses through leaching, runoff, volatilization, and other processes, causing groundwater contamination and eutrophication of water bodies. Due to these losses, nitrogen use efficiency in rice cultivation in India remains quite low, generally around 20-25% (Pramanick *et al.*, 2020) [16]. Such low N use-efficiency also creates a big concern for the Indian economy. Currently, about INR 79600 Cr subsidies have been given by GOI accounting for about INR 900 per bag subsidy for urea (Business Standard, 2021). So, if the use-efficiency of N-fertilizer has been increased through better agronomy then it would have been very beneficial for the overall economics of the nation.

Nanotechnology offers the potential to develop fertilizers with desired chemical compositions that can improve nutrient use efficiency, enhance crop productivity, and reduce environmental pollution. Therefore, nanotechnology can play an important role in balanced nutrient management and sustainable agriculture. Nano-fertilizers also have wide-ranging applications in agriculture and food processing systems (Kim *et al.*, 2018) [9]. Nano-fertilizers have great

potential to improve fertilizer use efficiency because they are required in smaller quantities and are generally more efficient than conventional fertilizers. Most nano-fertilizers are applied through foliar spray for better nutrient absorption. Several studies have also indicated that nano-urea can partially replace conventional granular urea, with the potential to substitute nearly 50% of its requirement (Kumar *et al.*, 2020) [10]. Studies have reported that supplying 50% nitrogen through conventional fertilizers and the remaining 50% through nano-N foliar spray, along with a single spray of nano-Zn and nano-Cu, significantly improved the yield of wheat, maize, and barley. However, information on the use of nano-N fertilizers in transplanted rice is still limited.

Nano fertilizer feeds the agricultural plant in a regulated and progressive manner. In contrast to chemical fertilizer fast and spontaneous release of nutrients (Singh, 2020) [10]. Nano-fertilizers can enhance nutrient use efficiency, minimize soil toxicity, and reduce the adverse effects associated with excessive fertilizer application and frequent use, thereby lowering production costs. Due to their small particle size and larger surface area, nano-fertilizers are easily absorbed and translocated within plants, which promotes photosynthesis, increases dry matter accumulation, and ultimately improves crop yield (Pandey, 2018) [15].

Nanotechnology has emerged as an efficient and innovative tool in modern agricultural research. Due to their extremely small size (1-100 nm) and large surface area, nanoparticles exhibit rapid action and improved efficiency, making them increasingly popular in agriculture. Nano urea particles are much smaller than conventional urea granules, which facilitates quick absorption and utilization by plants. Foliar application of IFFCO Nano Urea at 2-4 ml per litre during critical growth stages has been found beneficial for crop growth and development.

Nano-fertilizers enable precise nutrient application, helping to reduce fertilizer consumption, application costs, and environmental pollution while improving nutrient use efficiency. Their efficient absorption and translocation within plant tissues contribute to enhanced crop productivity and better economic returns. Nano urea particles can easily pass through stomata and plasmodesmata, allowing rapid movement within the plant system and active participation in metabolic processes. (Dutta *et al.*, 2021) [5].

Materials and Methods

The field experiment was conducted during the Rabi season of 2025 at Agronomy Research farm of Rama University, Kanpur Uttar Pradesh. The soil of the experimental field was sandy clay loam in texture, neutral in reaction (pH 7.2), which is common in the district's alluvial soils. The soil was low in available nitrogen (246.60 kg ha⁻¹) as determined by the alkaline permanganate method (Subbiah and Asija). The available phosphorus content was medium (14.5 kg ha⁻¹), estimated by Olsen's method (Olsen *et al.*, 1954). The soil was found medium to moderately high in available potassium (294.40 kg ha⁻¹), determined through the flame photometric method (Metson) at 0-15 cm soil depth prior to the initiation of the experiment. These fertility levels are generally representative of the Indo-Gangetic alluvial soils of the district.

The research was carried out in randomized block design with three replications. The nine treatment T₁-Control

(100% P & K), T-2 100% RDN & 100% P & K, T-3 75%N RDN & 100% P & K, T₄-T₂ + Nano N Spray at 30 DAT, T₅-T₂ + Nano N Spray at 45 DAT, T₆-T₂ + Nano N Spray at 30 & 45 DAT, T₇-T₃ + Nano N Spray at 30 DAT, T₈-T₃ + Nano N Spray at 45 DAT, T₉-T₃ + Nano N Spray at 30 & 45 DAT.

Result and Discussion

A. Growth Parameter

1. Plant population

Data presented in Table 1 revealed that there is no significant influence of traditional and nano forms of fertilizers on the initial and final plant population. Thus, the plant population was almost unvaried in all the plots.

2. Plant height (cm)

Plant height was recorded at different growth stages of the crop is presented in Table 2.

At 30 DAT, plant height did not differ significantly among treatments as nano fertilizer spraying had not been applied. At 60 DAT, the maximum plant height (68.8 cm) was recorded in T₆ (T₂ + Nano N spray at 30 & 45 DAT), which was statistically at par with T₄ (67.32 cm) and T₉ (65.82 cm), while the minimum plant height (41.92 cm) was observed in T₁ [Control (100% P & K)]. Similar trends were observed at 90 DAT and at harvest, where T₆ recorded the highest plant height and remained at par with T₄ and T₉, whereas T₁ showed the lowest plant height. These results were quite similar to the results of Marimuthu and Surendra (2015)^[13] and Benzon *et al.* (2015)^[3]

3. Leaf area (cm²)

The data pertaining to leaf area at different growth stages was registered and was presented in Table 3.

At 30 DAT, leaf area did not differ significantly among treatments, though the maximum leaf area (490.7 cm²) was recorded in T₃ (75% N RDN + 100% P & K). At 60 DAT, T₆ (T₂ + Nano N spray at 30 & 45 DAT) recorded the highest leaf area (1026 cm²), which was at par with T₄ and T₉, while T₁ (Control - 100% P & K) showed the minimum

leaf area. Similar trends were observed at 90 DAT and at harvest, where T₆ recorded maximum leaf area and remained statistically at par with T₄ and T₉, whereas T₁ recorded the lowest leaf area. These results were quite similar to the results of Dhoke *et al.* (2013)^[4] and Mahmoodzadeh *et al.* (2013)^[12].

4. Number of tillers (m⁻²)

The data pertaining to number of tillers m⁻² as influenced by the application of traditional and nano forms of fertilizers is presented in Table 4.

At 30 DAT, no significant difference in number of tillers m⁻² was observed among treatments, though T₃ (75% N RDN + 100% P & K) recorded the maximum tillers (290). At 60 DAT, the highest number of tillers m⁻² (453) was recorded in T₆ (T₂ + Nano N spray at 30 & 45 DAT), which was at par with T₄ (444) and T₉ (432), while the minimum tillers (273) were observed in T₁ (Control - 100% P & K). Similar trends were observed at 90 DAT and at harvest, where T₆ recorded maximum tillers and remained statistically at par with T₄ and T₉, whereas T₁ recorded the minimum number of tillers. These results were quite similar to the results of Armin *et al.* (2014) and Benzon *et al.* (2015)

5. Dry matter production (kg ha⁻¹)

Dry matter accumulation increased progressively with crop growth. At 30 DAT, treatments showed no significant difference, though T₃ (75% N RDN + 100% P & K) recorded higher dry matter accumulation (3015 kg ha⁻¹). At 60 and 90 DAT, T₆ (T₂ + Nano N spray at 30 & 45 DAT) recorded maximum dry matter accumulation and remained at par with T₄ and T₉, while T₁ (Control - 100% P & K) recorded the minimum values. At harvest, the highest dry matter accumulation (14982 kg ha⁻¹) was observed in T₉ (T₃ + Nano N spray at 30 & 45 DAT), which was at par with T₈, whereas T₁ recorded the lowest dry matter accumulation (7722 kg ha⁻¹). These results were quite similar to the results of Hafeez *et al.* (2015)^[7] and Rathnayaka *et al.* (2018)^[17].

Table 1: Influence of nano nitrogen on plant stand m⁻² of rice

Treatment		Initial population	Final population
T ₁	Control (100 % P & K)	39	36
T ₂	100 % RDN & 100 % P & K	38	37
T ₃	75 % N RDN & 100 % P & K	40	38
T ₄	T ₂ + Nano N Spray at 30 DAT	40	39
T ₅	T ₂ + Nano N Spray at 45 DAT	41	39
T ₆	T ₂ + Nano N Spray at 30 & 45 DAT	41	40
T ₇	T ₃ + Nano N Spray at 30 DAT	39	37
T ₈	T ₃ + Nano N Spray at 45 DAT	40	37
T ₉	T ₃ + Nano N Spray at 30 & 45 DAT	39	38
SE(m)±		2.33	2.22

Table 2: Influence of nano nitrogen on plant height (cm) of rice

Treatments		30 DAT	60 DAT	90 DAT	At Harvest
T ₁	Control (100% P & K)	34.62	41.92	54.22	68.92
T ₂	100% RDN & 100% P & K	40.02	59.52	88.42	102.82
T ₃	75%N RDN & 100% P & K	41.22	61.42	92.22	103.92
T ₄	T ₂ + Nano N Spray at 30 DAT	38.22	67.32	98.02	110.92
T ₅	T ₂ + Nano N Spray at 45 DAT	39.62	62.82	93.02	104.42
T ₆	T ₂ + Nano N Spray at 30 & 45 DAT	37.32	69.92	100.32	113.32
T ₇	T ₃ + Nano N Spray at 30 DAT	40.22	56.22	84.32	90.32
T ₈	T ₃ + Nano N Spray at 45 DAT	38.42	59.02	86.72	95.32
T ₉	T ₃ + Nano N Spray at 30 & 45 DAT	38.92	65.82	96.92	108.72
SE(m)±		2.35	1.85	2.09	2.39
CD (P = 0.05)		NS	5.6	6.4	7.3

Table 3: Influence of nano nitrogen on leaf area (cm²) of rice

Treatment		30 DAT	60 DAT	90 DAT	At Harvest
T ₁	Control (100% P & K)	454.7	654.2	541.3	290.3
T ₂	100% RDN & 100% P & K	477.0	928.6	862.8	410.6
T ₃	75%N RDN & 100% P & K	490.7	933.8	873.3	416.6
T ₄	T ₂ + Nano N Spray at 30 DAT	465.0	987.3	933.1	437.1
T ₅	T ₂ + Nano N Spray at 45 DAT	466.6	941.7	881.1	432.6
T ₆	T ₂ + Nano N Spray at 30 & 45 DAT	482.0	1026.0	959.2	419.2
T ₇	T ₃ + Nano N Spray at 30 DAT	473.0	900.6	812.2	347.2
T ₈	T ₃ + Nano N Spray at 45 DAT	488.0	919.7	835.9	374.7
T ₉	T ₃ + Nano N Spray at 30 & 45 DAT	458.0	983.7	928.2	430.3
SE(m)±		12.61	28.1	18.0	7.8
CD (P = 0.05)		NS	82.5	53.0	23.0

Table 4: Influence of nano nitrogen on number of tillers m⁻² of rice

Treatment		30 DAT	60 DAT	90 DAT	At Harvest
T ₁	Control (100% P & K)	287.0	273.0	269.0	265.0
T ₂	100% RDN & 100% P & K	288.0	414.0	372.0	351.0
T ₃	75%N RDN & 100% P & K	290.0	418.0	384.0	356.0
T ₄	T ₂ + Nano N Spray at 30 DAT	287.0	444.0	419.0	384.0
T ₅	T ₂ + Nano N Spray at 45 DAT	285.0	421.0	389.0	369.0
T ₆	T ₂ + Nano N Spray at 30 & 45 DAT	282.0	453.0	423.0	393.0
T ₇	T ₃ + Nano N Spray at 30 DAT	279.0	404.0	342.0	332.0
T ₈	T ₃ + Nano N Spray at 45 DAT	273.0	412.0	357.0	335.0
T ₉	T ₃ + Nano N Spray at 30 & 45 DAT	288.0	439.0	413.0	379.0
SE(m)±		7.1	9.3	9.1	7.6
CD (P = 0.05)		NS	28.4	26.8	22.8

Table 5: Influence of nano nitrogen on dry matter production (kg ha⁻¹) of rice

Treatment		30 DAT	60 DAT	90 DAT	At harvest
T ₁	Control (100% P & K)	2772.0	4258.0	5722.0	7722.0
T ₂	100% RDN & 100% P & K	2853.0	8133.0	10422.0	14157.0
T ₃	75%N RDN & 100% P & K	3015.0	8202.0	10539.0	14204.0
T ₄	T ₂ + Nano N Spray at 30 DAT	2793.0	8582.0	11237.0	14100.0
T ₅	T ₂ + Nano N Spray at 45 DAT	2790.0	8222.0	10661.0	14242.0
T ₆	T ₂ + Nano N Spray at 30 & 45 DAT	2812.0	8893.0	11348.0	14128.0
T ₇	T ₃ + Nano N Spray at 30 DAT	2904.0	7721.0	10165.0	13248.0
T ₈	T ₃ + Nano N Spray at 45 DAT	2927.0	7972.0	10243.0	13783.0
T ₉	T ₃ + Nano N Spray at 30 & 45 DAT	2794.0	8550.0	11199.0	14982.0
SE(m)±		87	217	224	251
CD (P = 0.05)		NS	647	666	720

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