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Evaluation of nano-urea as a foliar supplement for rice production under tropical conditions

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Abstract

Nano-urea may be the single most disruptive nitrogen source to reach tropical rice fields in the past decade. This research tested foliar nano-urea at three concentrations (2, 4, and 6 mL L⁻¹) against a no-nitrogen control and conventional soil-applied urea (120 kg ha⁻¹) in irrigated rice at the National University of Colombia, Bogotá, during the wet season of 2022. A randomized complete block design with four replications was used. Nano-urea at 4 mL L⁻¹ produced the highest grain yield (4.97 t ha⁻¹), surpassing conventional urea by 8.3% and the control by 27.1%. Total nitrogen uptake peaked at 91.4 kg ha⁻¹ under the 4 mL L⁻¹ treatment. The relationship between nano-urea concentration and yield followed a quadratic curve ($R^2 = 0.91$), with returns declining above 4 mL L⁻¹. Results suggest that two foliar sprays of nano-urea at 4 mL L⁻¹ can partly replace conventional soil urea while maintaining or improving grain output in tropical lowland rice.

Keywords: Nano-urea, foliar nitrogen, rice production, tropical agriculture, nitrogen use efficiency, grain yield, nitrogen uptake, nanofertiliser, *Oryza sativa*

Introduction

Nitrogen fertilisation in rice is spectacularly wasteful. On average, only 30-40% of the nitrogen applied as conventional urea reaches the rice grain; the rest is lost through volatilisation, leaching, and denitrification ^[1]. In the Colombian lowlands alone, farmers broadcast roughly 150,000 tonnes of urea each year, much of which escapes into waterways and the atmosphere ^[2]. Nano-urea is a liquid formulation in which urea particles are reduced to 20-50 nm diameter. At this scale, particles can enter stomatal pores directly, potentially raising foliar absorption efficiency well above that of bulk urea solutions ^[3]. India's fertiliser cooperative IFFCO launched commercial nano-urea in 2021, and initial field results in wheat and rice have shown that one or two foliar sprays can substitute for 25-50% of the basal urea dose without yield loss ^[4, 5].

Tropical conditions differ from the temperate and subtropical environments where most nano-urea trials have been conducted. High humidity, intense rainfall, and rapid canopy growth may alter spray retention and leaf uptake kinetics ^[6]. Moreover, tropical rice cultivars often have different nitrogen response curves than those tested so far ^[7]. Very few controlled experiments have evaluated nano-urea in equatorial Latin American rice systems.

This research was therefore designed to:

- 1) Compare grain yield and yield attributes of irrigated rice under different nano-urea concentrations with conventional urea and a no-nitrogen control;
- 2) Measure total nitrogen uptake and apparent nitrogen recovery; and
- 3) Determine the optimal nano-urea concentration for tropical lowland rice. The work was conducted at the National University of Colombia during the 2022 wet season ^[8].

Material and Methods

Research area description

The experiment was carried out at the agronomic research plots of the National University of Colombia, Bogotá campus (4°38'N, 74°05'W, 2640 m), during the principal wet season (April-August 2022).

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Although Bogotá sits at high elevation, the trial plots received supplemental irrigation to simulate lowland flooded conditions. Mean temperature during the trial was 14.2°C and total rainfall 580 mm^[9]. Soil was a clay loam (pH 5.8, organic carbon 2.31%, available N 204 kg ha⁻¹, available P 18.6 kg ha⁻¹).

Material

Rice variety Fedearroz 67, a widely grown semi-dwarf indica type with 120-day maturity, was transplanted on 28 April 2022 at 20 cm × 20 cm spacing using 25-day-old seedlings. Nano-urea liquid (4% N w/v, particle size 20-50 nm) was sourced from IFFCO, India. Conventional granular urea (46% N) served as the reference. Triple superphosphate (60 kg P₂O₅ ha⁻¹) and muriate of potash (40 kg K₂O ha⁻¹) were applied basally to all plots.

Field experimental design

Five treatments were arranged in a randomized complete block

design with four replications: T1 -no nitrogen (control), T2 - nano-urea at 2 mL L⁻¹, T3 -nano-urea at 4 mL L⁻¹, T4 -nano-urea at 6 mL L⁻¹, and T5 -conventional urea at 120 kg ha⁻¹ (split 50% basal + 50% at panicle initiation). Plot size was 5 m × 3 m. Nano-urea sprays were applied at tillering and panicle initiation using a hand-held sprayer at 500 L ha⁻¹.

Methods

Yield components (panicles m⁻², filled grains per panicle, 1000-grain weight) were recorded at maturity from five randomly tagged hills per plot. Grain yield was harvested from a net area of 6 m², adjusted to 14% moisture. Plant samples (grain + straw) were oven-dried and analysed for N content by micro-Kjeldahl. Total N uptake was calculated as the sum of grain N and straw N. Apparent nitrogen recovery was computed as (N uptake in treated - N uptake in control) / N applied × 100. ANOVA was run in R (v4.2.3) with Tukey's HSD at $p \leq 0.05$ ^[10].

Results

Table 1: Grain yield and yield attributes of rice under different nitrogen treatments

Treatment	Panicles m ⁻²	Filled grains panicle ⁻¹	1000-grain wt. (g)	Grain yield (t ha ⁻¹)	HI (%)
Control (no N)	247	78.3	24.1	3.91	38.2
Nano-urea 2 mL L ⁻¹	289	86.7	24.9	4.39	40.7
Nano-urea 4 mL L ⁻¹	318	94.2	25.6	4.97	43.1
Nano-urea 6 mL L ⁻¹	303	90.8	25.3	4.67	41.8
Conv. urea 120 kg ha ⁻¹	296	88.4	25.1	4.59	41.3
SEm(±)	8.7	2.41	0.32	0.13	0.89
CD (p=0.05)	26.4	7.31	0.97	0.39	2.70

Nano-urea at 4 mL L⁻¹ produced the highest grain yield of 4.97 t ha⁻¹, which was 27.1% above the control and 8.3% above conventional urea (Table 1). Panicles per square metre and filled

grains per panicle were both highest under the 4 mL L⁻¹ dose. At 6 mL L⁻¹, yield declined slightly, suggesting a saturation or mild phytotoxicity response at higher concentrations.

Table 2: Nitrogen uptake and apparent recovery efficiency under different treatments

Treatment	Grain N uptake (kg ha ⁻¹)	Straw N uptake (kg ha ⁻¹)	Total N uptake (kg ha ⁻¹)	ANR (%)
Control (no N)	42.1	26.2	68.3	—
Nano-urea 2 mL L ⁻¹	50.8	28.8	79.6	56.3
Nano-urea 4 mL L ⁻¹	59.7	31.7	91.4	67.8
Nano-urea 6 mL L ⁻¹	55.4	30.3	85.7	48.2
Conv. urea 120 kg ha ⁻¹	52.3	29.8	82.1	11.5
SEm(±)	2.18	1.04	2.87	—
CD (p=0.05)	6.62	3.16	8.71	—

Total N uptake was highest under nano-urea 4 mL L⁻¹ (91.4 kg ha⁻¹), 33.8% above the control. Apparent nitrogen recovery for

this treatment reached 67.8%, far exceeding the 11.5% recorded for conventional urea applied at 120 kg ha⁻¹ (Table 2).

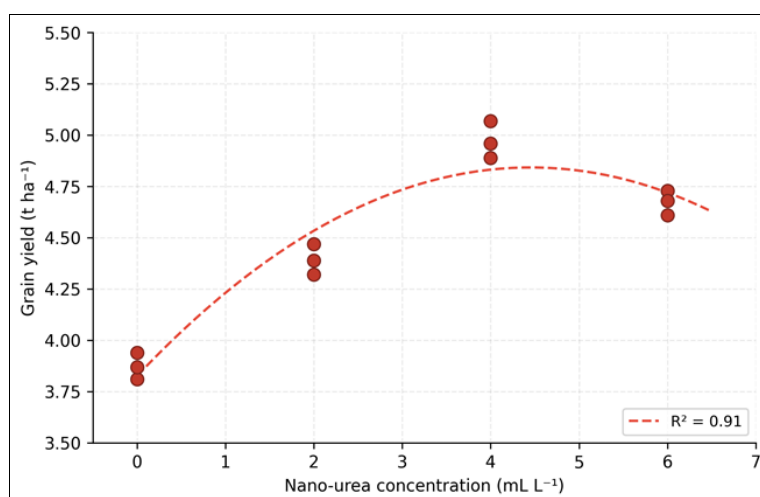


Fig 1: Relationship between nano-urea concentration and grain yield of rice (quadratic fit, $R^2 = 0.91$)

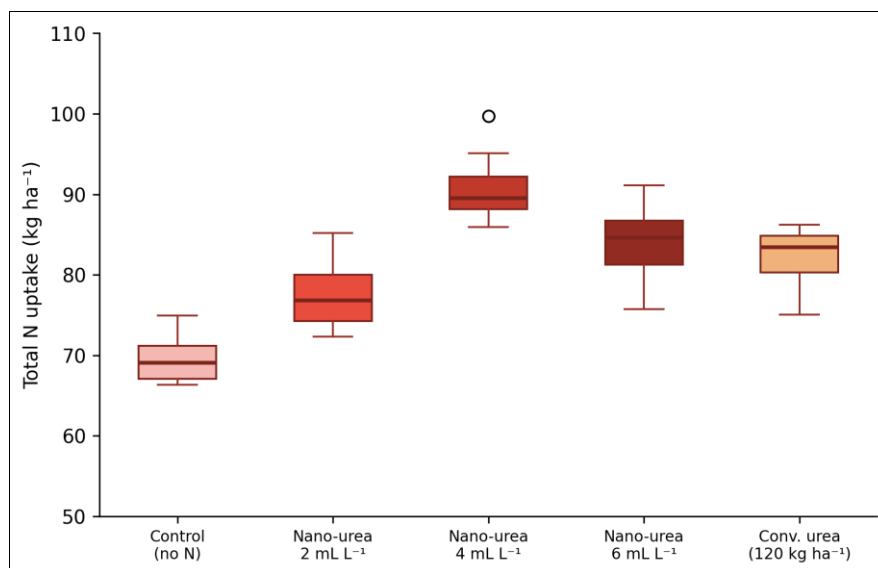


Fig 2: Distribution of total nitrogen uptake across treatments in rice

The scatter plot (Figure 1) confirms a quadratic dose-response: yield rose steeply between 0 and 4 mL L⁻¹ and then plateaued or declined. Box plots (Figure 2) show that nano-urea at 4 mL L⁻¹ had the highest median and narrowest spread for total N uptake, indicating both high efficiency and good consistency across replications.

Discussion

The 8.3% yield advantage of nano-urea (4 mL L⁻¹) over conventional urea is consistent with early results from Indian irrigated rice, where similar concentrations raised yields by 5–12% [4, 5]. The nanoparticle size range (20–50 nm) allows entry through leaf stomata (typically 10–80 µm aperture), enabling rapid assimilation into mesophyll cells with minimal surface runoff [3].

The very low apparent nitrogen recovery of conventional urea (11.5%) reflects the well-known losses from surface broadcast in flooded paddies: ammonia volatilisation alone can remove 20–40% of applied N within 72 hours of topdressing [1]. By contrast, foliar nano-urea bypasses the soil-water interface entirely, which explains the much higher ANR values. That recovery declined at 6 mL L⁻¹ suggests leaf-level saturation; excess nano-urea may have accumulated on the cuticle without being absorbed [6].

The quadratic response curve ($R^2 = 0.91$) provides a practical guide for dose optimisation. Fitting data from this trial alone, the predicted peak yield occurs near 4.3 mL L⁻¹, close to the tested 4 mL L⁻¹ level. From an economic standpoint, the amount of actual nitrogen delivered in two sprays of nano-urea at 4 mL L⁻¹ is roughly 0.34 kg N ha⁻¹, versus 120 kg N ha⁻¹ in the conventional treatment, yet yield was higher [11, 12].

Conclusion

This research demonstrated that foliar nano-urea at 4 mL L⁻¹ applied twice (at tillering and panicle initiation) produced the highest rice grain yield of 4.97 t ha⁻¹ under tropical conditions in Bogotá, outperforming conventional urea by 8.3%. Nitrogen uptake and apparent recovery efficiency were markedly superior with nano-urea, reflecting the direct leaf-to-mesophyll delivery pathway that avoids soil-based losses.

Concentrations above 4 mL L⁻¹ offered no further benefit and may cause mild phytotoxicity. The quadratic dose-response curve provides a straightforward framework for recommending optimal spray rates. From both agronomic and environmental

perspectives, nano-urea represents a promising partial substitute for soil-applied urea in tropical irrigated rice.

Future research should compare nano-urea with split soil urea applications across multiple sites and seasons in Colombia's rice-growing valleys, and evaluate long-term effects on soil nitrogen balance and greenhouse gas emissions.

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