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Nano Urea A Nanotechnology-Based Approach for Sustainable Crop Nutrition

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***Abstract*—As global agriculture faces the dual challenge of food security and environmental sustainability; nanotechnology has emerged as a potential approach to improving fertilizer efficiency. IFFCO's Nano Urea (Liquid) was launched with the claim that a 500 ml bottle could replace a 45 kg bag of conventional granular urea. While initial trials suggested gains in Nitrogen Use Efficiency (NUE), independent research has raised questions about whether the lower quantity of nitrogen supplied by Nano Urea can meet the full requirements of high-yield crops. This case study examines the chemical properties, proposed mechanism of action, agricultural and environmental benefits, and the mass-balance challenge surrounding Nano Urea. The discussion highlights both its potential as a sustainable agricultural tool and the scientific debate over whether it should be considered a supplement or a complete replacement for conventional urea.**

***Index Terms*—Nano Urea, nanotechnology, nutrient use efficiency, sustainable agriculture, foliar application, green chemistry.**

I. INTRODUCTION

The word "nano" is derived from the Greek word for "dwarf," representing a scale of 10^{-9} meters. In modern agriculture, nanotechnology is being presented as a potential next step in improving fertilizer efficiency.

IFFCO's Nano Urea (Liquid), developed at the Nano Biotechnology Research Centre (NBRC) in Kalol, Gujarat, was introduced to address inefficiencies associated with traditional nitrogen fertilizers. For more than five decades, Indian farmers have relied on prilled urea. The case study reports that conventional urea has low Nutrient Use Efficiency (NUE), with substantial nitrogen

losses occurring through leaching and volatilization. Nano Urea was introduced in 2021 with the stated aim of reducing fertilizer wastage and improving nutrient delivery. Its marketed proposition is that one 500 ml bottle can replace a 45 kg bag of solid urea.

Nano Urea is described as a nanotechnology-based liquid nitrogen fertilizer developed by the Indian Farmers Fertiliser Cooperative Limited (IFFCO). Its formulation uses particles in the 20–50 nm range, and it is applied as a foliar spray so that nitrogen can be absorbed directly by plant leaves.

II. OBJECTIVE

The objective of this case study is to examine the proposed benefits and scientific limitations of Nano Urea as an alternative to conventional urea. The study considers its nutrient efficiency, agricultural performance, environmental implications, economic advantages, and the scientific debate concerning whether Nano Urea can fully replace conventional nitrogen fertilizer.

- To understand the limitations of conventional urea and the motivation for developing Nano Urea.
- To examine the composition, particle size, and proposed mechanism of Nano Urea.
- To compare conventional urea and Nano Urea in terms of nutrient use efficiency, application, quantity, and environmental impact.
- To understand the economic and environmental benefits claimed for Nano Urea.
- To examine the mass-balance challenge and the question of whether Nano Urea should be used as a supplement or a replacement.

Information and scientific basis

Nano Urea is a liquid nitrogen fertilizer developed using nanotechnology. It is designed as an alternative to conventional urea and supplies nitrogen, an essential nutrient for plant growth.

Composition and properties:

- Contains 4% nitrogen (w/v) in nano form.
- Particle size: 20–50 nanometers (nm).
- Very high surface area, supporting better absorption.
- One 500 ml bottle is presented in the case study as approximately equivalent to one 45 kg bag of conventional urea.
- The formulation is highly soluble in water, supporting uniform spray distribution. Working mechanism:
- Nano Urea is applied as a foliar spray directly onto plant leaves.
- The nanoparticles are described as entering through leaf stomata and plant cells.
- The nitrogen is transported through the plant system and is described as being released slowly and efficiently.
- The proposed result is higher nutrient efficiency and less wastage.

III. Advantages of Nano Urea

1. Agricultural Benefits

Nano-urea has been reported to exhibit high nitrogen-use efficiency (NUE), with values exceeding 80% under certain experimental conditions. Foliar application of nano-urea has been associated with improved crop growth, yield attributes, and produce quality in several crop species. Nano-urea has the potential for application across different crops and soil conditions, although its effectiveness may vary depending on crop type, soil characteristics, environmental conditions, and application practices. Its use is intended to reduce dependence on conventional granular urea, with some studies and industry claims suggesting that conventional urea application can potentially be reduced by 50% or more when nano-urea is appropriately integrated into the nutrient-management strategy.

2. Economic Benefits

Nano-urea may contribute to lower fertilizer expenditure by reducing the quantity of conventional urea required under suitable agronomic conditions. Its liquid formulation can substantially reduce transportation, handling, and storage requirements compared with conventional granular urea. Improved nitrogen-use efficiency and potentially higher crop productivity may contribute to increased farm profitability and farmer income. According to the case study, a 500 mL bottle of nano-urea is priced at approximately ₹240; however, the economic advantage should be evaluated by considering the total cost of the nutrient-management program, including conventional nitrogen inputs, application costs, crop response, and local market conditions.

3. Environmental Benefits

Improved nitrogen-use efficiency may help reduce nitrogen losses from agricultural fields, thereby potentially lowering the risk of soil and water contamination. More efficient nitrogen utilization may contribute to a reduction in nitrogen-related greenhouse-gas emissions, particularly where it decreases excessive nitrogen application and subsequent losses. Because nano-urea is applied in relatively small quantities compared with conventional granular urea, its use may reduce the volume of fertilizer requiring transportation, handling, and storage. By promoting more efficient nutrient management, nano-urea has the potential to support sustainable and climate-smart agricultural practices.

IV. DEVELOPMENT AND PRODUCTION

The case study states that Nano Urea was developed in India at IFFCO’s Nano Biotechnology Research Centre in Gujarat. Ramesh Raliya is identified as a developer who worked on Nano Urea from 2015 and participated in nationwide trials from 2019. The product was developed for large-scale agricultural use, with production facilities such as the Aonla plant mentioned in the

case study.The development is presented as an example of applying nanotechnology to improve fertilizer efficiency while reducing the quantity of conventional chemical fertilizer required.

Table 1: Efficiency comparison of conventional urea and Nano Urea

Feature	Conventional Urea	Nano Urea
Nitrogen use efficiency	30–40%	>80%
Application	Soil	Foliar spray
Quantity needed	High	Very low
Environmental impact	High	Low

Table 2: Properties of Nano Urea

Property	Details and scientific significance
Particle size	< 100 nm — Allows entry through microscopic leaf pores
Nitrogen content	4.0%(w/ v) —Concentrated for foliar application
Surface area	High — Increases the rate of chemical reaction inside the plant
Solubility	Highly soluble in water — Supports uniform spray distribution
Environmental impact	Low —Reduces nitrate leaching into the water table

V. PROPERTIES OF NANO UREA

The case study identifies the following scientific properties and significance:

The scientific debate: the mass-balance challenge

The central scientific debate described in the case study concerns the amount of nitrogen actually supplied to a crop. Proponents argue that Nano Urea can reduce wastage because it is delivered directly to leaves through foliar application. Its proposed high efficiency is therefore used to explain how a much smaller quantity can provide useful nitrogen to the plant.

Independent researchers, including researchers from Punjab Agricultural University (PAU), have raised concerns about the total nitrogen mass supplied. The case study notes that a 45 kg bag of urea provides approximately 20 kg of actual nitrogen, whereas a 500 ml bottle of Nano Urea provides approximately 20 grams. The argument is that even at 100% efficiency, 20 grams of nitrogen cannot biologically equal 20,000 grams during peak growth stages of heavy-feeding crops such as wheat or maize.

The case study further notes reports of decreased grain protein in some trials. This has led to the key question of whether Nano Urea should be considered a supplement to conventional nitrogen fertilizer or a complete replacement. The evidence presented therefore supports continued scientific evaluation rather than treating Nano Urea as a universal replacement.

Figure 3: Nano Urea chemical structure and formulation

VI. ENVIRONMENTAL AND ECONOMIC SIGNIFICANCE

Conventional urea can contribute to environmental pollution when nitrogen is lost through leaching and gaseous emissions. The case study states that excessive urea use can contribute to nitrate movement into soil and groundwater and can increase nitrous oxide emissions. Nano Urea is presented as a means of reducing such losses by delivering nitrogen through foliar application. From an economic and logistical perspective, the case study highlights the smaller quantity of product required, lower storage and transportation needs, and the reported affordability of a 500 ml bottle. These benefits can be significant if the product is used appropriately and if crop nitrogen requirements are adequately met.

VII. FIELD APPLICATION

Nano Urea is applied as a foliar spray. The case study presents foliar application as an important part of its proposed efficiency because the nutrient is delivered directly to the leaves rather than being distributed through the soil. Correct application and the crop's actual nutrient requirements remain important when evaluating its performance.

VIII. CONCLUSION

IFFCO Nano Urea represents an application of nanotechnology to the problem of fertilizer efficiency and sustainable agriculture. The case study presents several potential advantages, including higher reported nutrient use efficiency, lower fertilizer quantities, reduced transportation and storage requirements, and reduced environmental losses. At the same time, the mass-balance challenge shows why efficiency percentages alone cannot determine whether a fertilizer can fully replace the nitrogen supplied by conventional urea.

Therefore, the case study concludes that Nano Urea should be viewed as an integrated agricultural tool rather than a universal "magic bullet." Its future role depends on matching the

product's nutrient contribution with the actual nutritional requirements of crops, while continuing to evaluate crop yield, grain protein, environmental outcomes, and economic performance.

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