

Nano-urea: The next-gen fertiliser for a greener future

**Biplab¹, Sovan Debnath^{1*}, Asha Ram¹, Badre Alam¹, Akash Yadav¹,
Susmit Saha² and Ayyanadar Arunachalam¹**

¹ICAR-Central Agroforestry Research Institute, Jhansi, Uttar Pradesh 284 003

²Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal 741 252

Cereals serve as a staple food source for more than 80% of the global population, making it essential to increase cereal production per unit area to meet the demands of the rapidly growing population. Nitrogen is an essential as well as primary nutrient for crop growth. Urea is the most commonly used nitrogen-based fertiliser, containing 46% nitrogen. However, the excessive application of urea can disrupt the natural composition of the soil, reduce its fertility and productivity and increase soil acidity. To address these issues, nano-urea has been recently developed as a step toward more sustainable and precise agriculture. Nano-urea has undergone biosafety and toxicity assessments in accordance with Indian regulations and internationally recognised guidelines. Nano-urea is a viable, environmentally friendly, and sustainable liquid nitrogen fertiliser that enhances nutrient availability to crops by ~80% and improves nitrogen use efficiency by 85–90%.

Keywords: Cereals, Nano-fertilisers, Nitrogen efficiency

GLOBAL agriculture relies heavily on chemical fertilisers to sustain crop productivity; however, their excessive and inefficient use has become a major environmental and economic concern. Global fertiliser consumption is projected to reach approximately 263 million tonnes (mt) by 2050, while fertiliser use has increased nearly 13-fold since 1950. Excessive fertiliser application result in low nutrient use efficiency, soil degradation, micronutrient depletion, environmental pollution, and adverse effects on beneficial soil microorganisms. Furthermore, nearly 50–70% of applied nutrients are lost through leaching, volatilisation, denitrification, and runoff, contributing to eutrophication and greenhouse gas emissions. These challenges highlight the need for innovative and sustainable nutrient management strategies. Nitrogen is a key macronutrient required for chlorophyll synthesis, protein

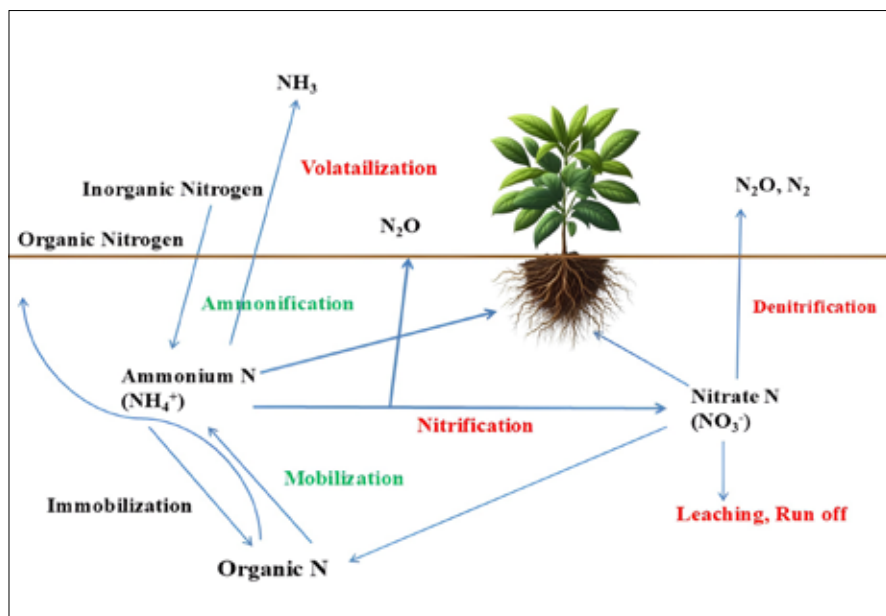
formation, enzymatic activity, and overall plant growth. India is the second-largest consumer and third-largest producer of urea, with annual consumption (19.1 mt) exceeding domestic production (13.68 mt), necessitating substantial imports. As urea constitutes nearly 82% of the country's fertiliser consumption and around 55% of global nitrogen fertiliser use, its extensive utilisation contributes significantly to national fertiliser subsidy expenditures. Moreover, conventional urea exhibits a nitrogen use efficiency of only 30–40%. Therefore, improving nitrogen use efficiency through advanced technologies such as nano-urea could help reduce dependence on conventional urea while lowering the economic burden of fertiliser subsidies.

Nanotechnology has emerged as a promising approach to overcome these limitations. Nano-urea, a next-generation fertiliser, enhances nitrogen use efficiency

through improved nutrient delivery while reducing environmental losses and nitrous oxide emissions. Consequently, nano-urea has considerable potential to partially replace conventional urea, improve crop productivity, reduce fertiliser inputs, and support environmentally sustainable and economically viable agricultural systems. These fertilisers are manufactured using chemical, physical, mechanical, or biological methods to enrich soil fertility, increase crop productivity, and enhance the quality of agricultural output.

Impact of nano-fertilisers on the growth and development of plants

Nano-fertilisers are designed to fulfill the nutritional needs of specific crops such as rice, wheat, maize, French bean, chickpea, pigeon pea, soybean, mustard, cotton, sugarcane, tomato, potato, etc. Their nano-sized structure enables precise



Soil nitrogen reactions that result in the loss of nitrogen fertilisers

and controlled release of active ingredients, minimising excess runoff, preventing eutrophication, and reducing residual contamination. By enhancing nutrient uptake efficiency, they help lower environmental protection costs and prevent soil salinity build-up, as they are required in smaller quantities. These benefits contribute to improved crop nutrition, better seasoning quality, and enhanced plant growth by preventing diseases and strengthening crop stability through deeper rooting and resistance to bending.

Consequently, nano fertilisers could serve as an alternative to traditional fertilisers by providing a sustained and regulated release of nutrients. However, their widespread adoption in agriculture comes with certain challenges that need careful consideration. In particular, assessing the toxicity and biocompatibility of nano fertilisers is essential before large-scale implementation.

Safety measures for nano-urea

Unlike traditional granular urea, it has a surface area almost 10,000 times larger relative to its volume, which gives it unique characteristics and benefits. Nano-urea has undergone biosafety and toxicity assessments in accordance with Indian regulations

and internationally recognised guidelines established by the OECD (The Organization for Economic Co-operation and Development), which are globally adopted.

Features of nano-urea

Nano-urea (Liquid), a next-generation nitrogen fertiliser, recognised as the first of its type worldwide and officially approved by the Government of India. It efficiently supplies nitrogen to crops through foliar application at critical growth stages, enhancing yield while minimising environmental impact. Due to its ultra-fine structure and surface properties, nano-urea is readily absorbed by plant leaves

upon spraying. The nanoparticles then travel to the plant's nitrogen-deficient areas, ensuring a well-balanced nutrient supply. It is considered as next-generation fertiliser because of some benefits listed below:

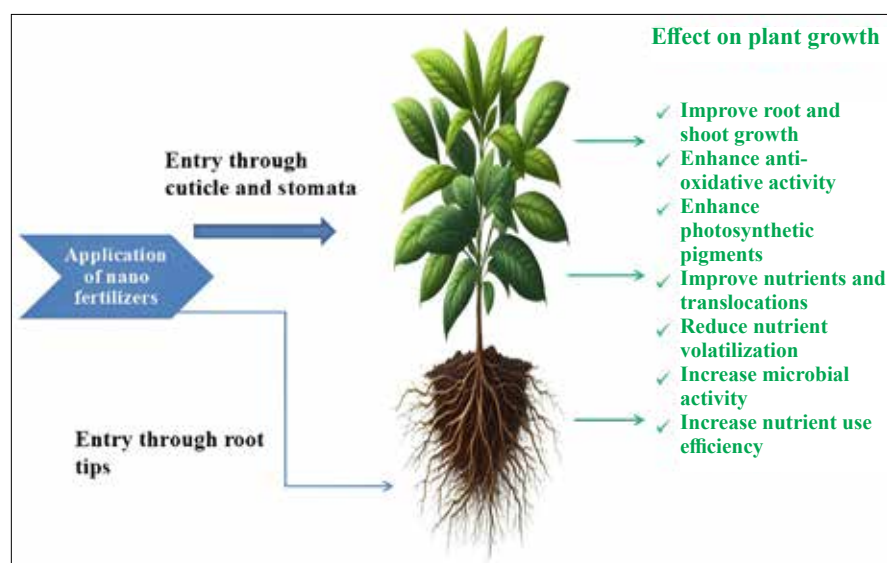
- Nano-urea decreases gaseous emissions and limits nutrient loss through leaching in agricultural fields, which helps reduce its environmental impacts.
- Highly suitable for drone-based fertiliser application.
- Enhances productivity with reduced input, allowing a significant decrease in urea or other nitrogen-based fertilisers without compromising yield. The requirement for urea can be reduced by at least 50%.
- Cost-effective and easier to transport and store.
- Crop quality is enhanced by it.
- Can lead to an approximately 5–20% increase in crop yield.
- Improves the efficiency of fertiliser use.
- Boosts fruit and vegetable quality.

Significance of nano-urea

Improves plant nutrition:

Nano-urea has proven to be highly effective and efficient in plant nutrition, enhancing crop yield while reducing the wastage of N fertiliser.

By reducing excessive urea application in the soil, it promotes



Impact of nano-fertilisers on the growth and development of plants

Table 1. Comparison between conventional urea and liquid nano-urea

Particulars	Conventional urea	Liquid nano-urea
Introduction year	1823	2021
Production technology	Made using the Bosch-Meiser process and urea granulation technology	Developed using nanotechnology
Particle size	Larger granules (~1 mm)	Extremely fine particles (~32 nm)
Nutrient use efficiency	Low (30–40%)	High (85–90%)
Cost	₹266.50/45 kg bag	₹240/500 mL bottle
Storage needs	Requires substantial storage area	Requires minimal storage space
Environmental impact	Causes air, water, and soil contamination	Environmentally safe
Evaporation loss	Subject to vapourisation	Does not evaporate
Soil residue	Leaves behind residues in soil	Leaves no residue in soil
Impact on soil health	Can lead to soil acidification	Do not cause soil acidification
Nutrient availability	Remain available for only 3–4 days	Accessible throughout plant's life
Effect on maturity	Excessive or late or single basal nitrogen application may prolong vegetative growth and delay crop maturity	Shown potential to timely crop maturity
Absorption method	Through root system	Taken up directly through leaves
Application method	Applied to soil as basal/top dressing or used as a foliar spray	Used only as a foliar spray

a balanced nutrition programme, strengthening crops, making them healthier, and protecting them from lodging.

Improves environment: Nano-urea has potential to improve the quality of groundwater, significantly reduce global warming, and contribute to climate change mitigation and sustainable development.

Increase farmers' income: Nano-urea seems to be cost-effective for farmers and may play a crucial role in boosting their income. Additionally, it may significantly reduce logistics and storage costs.

Nano-urea application

- Nano-urea should be sprayed in standing crop at the rate of 2 mL/L of water in crops with a low requirement of nitrogen and up to 4 mL in crops with a high requirement of nitrogen.
- It can be used twice in cereals, oil, vegetable, cotton, etc., and once in pulse crops.
- The initial spray should be applied 30–35 days after

germination or 20–25 days post-transplanting, while the second spray can be done either 20–25 days after the first application or about a week prior to flowering or budding.

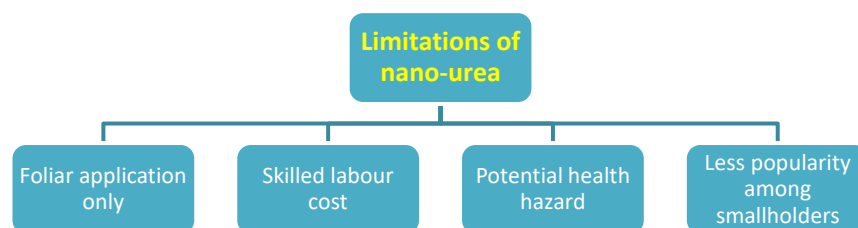
- For one acre of field, the amount of water per sprinkle is about 125 L.
- Use a flat-fan or cut-type nozzle for applying nano-urea.
- Spray during early morning or late evening hours, avoiding times of intense sunlight, wind, or dew.
- If rainfall occurs within 12 h of spraying, a reapplication is recommended.
- For safety, it is recommended to wear gloves and a face mask while spraying.

Contribution of nano-urea in improving nitrogen use efficiency and cereal crop yields

Cereals are part of the Poaceae family, which encompasses crops like rice, wheat, maize, sorghum, and barley. Since these crops share similar physiological processes, the effects of fertiliser application are generally alike. Cereal crops have a high nitrogen demand as they are heavy feeders. However, using conventional fertilisers like urea could lead to significant nitrogen loss through leaching, volatilisation, and denitrification. In contrast, using nano-urea during critical growth stages greatly improves plant development and crop yield.

Nano-urea is a slow-release, biodegradable nitrogen formulation that enters plants through stomatal openings. This ensures efficient nutrient absorption with minimal loss, thereby improving nitrogen use efficiency. Efficiency here refers to the output obtained per unit of applied input, nano-urea being the input and crop yield (kg/ha) as the output. Research has shown that applying 50% of the recommended nitrogen dose along with 50% nano-urea as a foliar spray results in the highest yield compared to other combinations.

Nano-urea enhances nitrogen absorption, accumulation, and assimilation, promoting better root growth, which in turn facilitates the uptake of other essential and beneficial nutrients. It also strengthens plant resistance to biotic and abiotic stress, stimulates enzymatic activity, and increases photosynthate accumulation in grains. This results in a higher number of panicles per square meter, more grains per panicle, and a greater proportion of filled grains, ultimately leading to improved economic and biological yield and a higher harvest index. Overall,





100% N through conventional urea



75% N through conventional urea + 25% Nanourea



Control plot (No Nitrogen)



25% N through conventional urea + 75% Nanourea

A field view of French bean experiment with nano-urea treatment

nano-urea enhances nitrogen use efficiency by approximately three times compared to conventional urea.

An experiment was conducted during the *rabi* season at Bidhan Chandra Krishi Viswavidyala, West Bengal, where 75% nitrogen through conventional urea + 25% nano-urea recorded superior and higher amount of biomass as well as yields of French bean

as compared to the control and others treatment combinations. The treatment combinations of 75% nitrogen through conventional urea + 25% nano urea recorded 32.12% and 19.41% higher yields and dry biomass of French bean as compared to the control, respectively.

SUMMARY

Advancements in science and technology have accelerated with

the emergence of nanotechnology, offering solutions to numerous challenges faced by farmers and the environment. Its application at the field level will not only enhance agricultural sustainability but also help conserve natural resources and protect the environment. Nano-urea represents a significant step toward sustainable agriculture and modern food systems, incorporating precision and innovative farming techniques. It holds the potential to transform the global agricultural sector. Compared to conventional urea, nano-fertilisers are more environmentally friendly while reducing input costs, logistics, and storage expenses. The long-term goal is to gradually replace a portion of conventional urea with nano-urea to improve nitrogen use efficiency and reduce environmental losses. This is how nano-urea can complement conventional urea. However, in certain cases, nano-urea has yet to demonstrate the same effectiveness as traditional fertilisers in enhancing crop growth and yield. Therefore, further extensive research and studies are required to fully understand its impact and optimise its application.

*Corresponding author email: sovan_t97@yahoo.com

Textbook on Environmental Pollution



This textbook provides a comprehensive overview of environmental pollution and its management. It systematically examines air, water, and soil pollution; the risks associated with heavy metals and hazardous substances; the growing challenge of solid waste; and the often-overlooked impacts of noise pollution. Emphasis is placed on recent scientific developments, modern monitoring techniques, innovative remediation strategies, and practical control measures that support environmental protection.

TECHNICAL ASPECTS

Pages: vi + 298; Price: ₹ 950.00, US\$ 140.00; Postage: ₹100

ISBN No.: 978-81-7164-310-3

For obtaining copies, please contact:

Business Unit

ICAR-Directorate of Knowledge Management in Agriculture

Krishi Anusandhan Bhawan – I, Pusa, New Delhi 110012

Tel: 011-25843657; email: businessuniticar@gmail.com

website: www.icar.gov.in

SCAN QR Code

