

Revolutionizing Crop Nutrition: The Importance of Nano Urea in Modern Agriculture

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Nano urea represents a transformative approach to crop nutrition, offering substantial benefits in terms of yield, environmental sustainability, and resource use efficiency compared to conventional fertilizers. Its application has revolutionized nitrogen delivery by leveraging nanotechnology, making it a pivotal tool in modern, sustainable agriculture.

What is Nano Urea?

Nano urea is a liquid fertilizer developed with nitrogen particles at the nanoscale (typically 20–50 nm), encapsulated for enhanced absorption. Unlike traditional urea, which is highly soluble and easily lost through leaching and volatilization, nano urea releases nitrogen slowly and is absorbed directly through leaves via foliar application. This targeted delivery enables more efficient nutrient uptake, reduced fertilizer wastage, and better physiological growth in crops.

Enhanced Crop Yield and Quality: Field trials and research across major crops- rice, wheat, maize, cotton, tomato, demonstrate 8–23% higher yields with nano urea application, often while reducing conventional fertilizer use by 25–50%. For instance, in rice, two sprays of nano urea during critical growth stages led to yield increases of 12–16% and a substantial reduction in mineral nitrogen use. The superior nutrient use efficiency results in improved crop biomass, photosynthetic rate, root development, protein content, and plant vigor.

- Wheat: 10–22% yield increase with 50% RDN substitution
- Rice: 12–16% yield increase, 25–34% fertilizer savings
- Maize: Comparable yields with 75% NPK + nano urea spray
- Tomato, cucumber, capsicum: 5–18% more yield and reduced fertilizer use

Economic Benefits for Farmers: Nano urea lowers input costs due to reduced fertilizer quantity required and increases farmers' income through better yields and quality. A single 500 ml bottle of nano urea can replace 50 kg of conventional urea, simplifying storage, transport, and application logistics. Economic analyses show that using nano urea alongside reduced doses of conventional fertilizers maintains or improves profit margins without yield penalty.

Environmental Sustainability: Like all nitrogen fertilizers, conventional urea contributes to environmental pollution via ammonia volatilization, nitrous oxide emissions, runoff, and nitrate leaching—factors that degrade water and air quality, and impact climate change. Nano urea's targeted delivery and slower release drastically reduce these losses. Reports show a 25% reduction in greenhouse gas emissions, improved soil health, and lower nitrate pollution in groundwater with nano urea use.

Improved Nutrient Use Efficiency: Nano urea enhances Nitrogen Use Efficiency (NUE), meaning crops derive more benefit from each unit of fertilizer applied. The small size and

high surface area of nanoparticles allow easy penetration into leaf cells, direct transport through stomatal pores, and better movement to grain, leaf, and root tissues. Studies show that application of nano urea increases the number of effective tillers, panicle length, grain output, and protein content in rice and other crops.

- In wheat, effective tillering and higher biomass are noted with recommended N + nano urea sprays
- In maize, integrating nano urea with reduced N achieves comparable net returns and yields
- For rice, applying nano urea improves nitrogen content in both grain (1.10%) and straw (0.65%), and boosts protein content

Reduced Chemical Fertilizer Usage: Nano urea helps cut chemical fertilizer requirements by up to 50% without yield sacrifices, thus lowering the national subsidy burden and reducing energy, water, and electricity required for fertilizer production. The direct foliar application avoids wasteful soil losses and enables precise timing for nutrition delivery. In rainfed and low-input agriculture, nano urea supports higher productivity with less input.

Application Technology and Adaptation: Nano urea can be applied using knapsack sprayers, drones, or manual foliar spray methods, making it accessible to both small and large-scale farmers. Its long shelf life and high portability further facilitate widespread adoption. Larger surface area-to-volume ratios of nano urea particles guarantee better leaf coverage and absorption during spraying.

Soil and Water Quality Preservation: Traditional urea's overuse depletes soil fertility, leads to leaching of N into water bodies, and causes nitrate accumulation to all detrimental to the environment. Nano urea helps sustain soil microbial activity, avoids runoff losses, and prevents excessive nitrous oxide emissions. Long-term integration of nano fertilizers improves soil structure and supports a healthy rhizosphere.

Role in Precision and Smart Agriculture: Nano urea is integral to precision agriculture, enabling farmers to deliver nutrients based on crop need, growth stage, and real-time field conditions. Its use aligns with 4R nutrient stewardship (right source, right rate, right time, right place), promoting sustainable farming and minimizing the agricultural carbon footprint.

Limitations and Future Prospects

While nano urea offers significant agronomic and sustainability advantages, long-term studies are needed to fully assess its impact on soil health, crop quality, and ecosystem dynamics. There remain challenges in standardizing application rates across diverse agro-ecological zones and ensuring regulatory oversight for quality and safety. Continued research will validate multi-year, multi-crop results and support policy integration at scale.

Summary Table: Nano Urea vs Conventional Urea

Parameter	Conventional Urea	Nano Urea
Dosage per hectare	45–50 kg N (granular)	500 ml (liquid)
Efficiency (N use)	30–40%	80–90%
Yield Improvement	Baseline	8–23% higher
Environmental Impact	Higher GHG, nitrate, runoff	Low GHG, minimal runoff
Cost and Logistics	High input, storage, bulky	Low input, portable, easy storage
Application	Soil (granular)	Foliar (liquid, nano spray)
Crop Quality	Standard	Improved protein, nutrition

Conclusion

Nano urea stands as a breakthrough in crop nutrition, greatly improving yield, quality, efficiency, and sustainability while minimizing environmental harm. Its adoption holds the promise of advancing Indian and global agriculture toward productive, climate-smart, and resource-efficient practices that benefit both farmers and the planet.