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Liquid Nano Urea: Step Forward to Smart Agriculture- A Review

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Abstract: Chemical fertilizer is necessary for the growth and development of crops. However, the efficiency of conventional chemical fertilizers is very low. Nowadays, fertilizer use efficiency (FUE) is the focus of agriculture cultivation practices to meet economic and environmental challenges. Around half of the total agricultural production relies on urea fertilizer, and the reduction in soil fertility has led to 3.56%. Liquid Nano Urea (LNU) can play a vital role in ensuring food security in Bangladesh. It can replace 50 % of conventional urea and can save subsidies to the govt. In addition, it is environmentally safe and reduces production costs, ensuring an increase in the total yield of 8-20%. Ensuring 90% work efficiency, the utilization of cutting-edge technologies and modern innovation in agricultural practices to enhance sustainability and efficiency in farming. Only two sprays of LNU can change the whole scenario of food safety. Recommended dose of optimize the use of nano urea for improved crop productivity and sustainability. The proper application of nano urea holds immense potential for enhancing crop production efficiency and sustainability.

Keywords: Liquid nano fertilizer; Nano urea; Smart agriculture; Food safety; Economic benefit.

INTRODUCTION

The major economic pillar of Bangladesh is agriculture. After 1971, agriculture contributed to GDP by around 60 percent but decreased to 11.50 percent by FY 2021-22 (BBS, 2022). Bangladesh needs a total of 6.84 million tons (approx.) of fertilizer for the upcoming 2023-24 fiscal year, and among all fertilizers, the demand for urea is about 26 lakh tons (MoA, 2023). Due to the reduction of soil fertility, around 3.56% of urea consumption increased per unit of arable land in 10 years (Suhan et al., 2021), and about 75 percent of fertilizer is used for rice cultivation (Zaman, 1987), where urea solely contributes to 70-75% of the total fertilizer usage (Jahiruddin et al., 2010). However, Bangladesh can produce about 10 lakh tons of urea fertilizer locally (Ali-TBS, 2021). Although, to meet the demand, Bangladesh needs to import 16 Lakh tons of Urea. According to the data of FY 2008-2023, Bangladesh spent for subsidy Tk 1,19,837 crores. The amount allocated for fertilizer subsidy in the upcoming budget (FY 2023-24) is expected to be approximately Tk 24,000 crore, which is an increase from the initial budget allocation (FY 2022-23) of Tk 16,000 crore for the current fiscal year (Byron-TDS, 2023).

Besides this, the use of chemical fertilizers has become a significant concern for the country's agriculture sector due to its adverse environmental impacts and high cost to farmers. Bangladesh needs to move towards smart agriculture to save a bulk amount of money. In this case, nanotechnology can change the scenario. It has been observed that around 40-70% of applied nitrogen fertilizer is lost in the environment and cannot reach the plant, resulting in huge economic losses (Trenkel, 2010; Solanki, 2015). To

attain a reduction in nutrient losses of a minimum of 50%, it is expected that a decrease in fertilizer application of at least 20% will be essential by the year 2030. (Seck, 2012).

The natural gas crisis, which affects fertilizer production, is identified as a major obstacle in Bangladesh, and the government is exploring options such as importing liquefied natural gas to address the situation (Suhan et al., 2021).

In recent years, the use of nano urea has emerged as a potential solution to these issues. Compared to traditional urea, nano urea is much smaller in size. It has a higher concentration of nitrogen, allowing for the same amount of nitrogen to be delivered in a smaller quantity. Additionally, the absorption rate is faster, allowing for better nutrient uptake by plants (Subramanian et al., 2015). The smaller size of nano urea particles means that the absorption rate is faster, allowing for better nutrient uptake by plants.

Configured as a nanoparticle, liquid nano urea is composed of nitrogen particles measuring between 20 and 50 nanometers in diameter, functioning as a liquid nitrogen supply for plants instead of conventional urea. The efficiency of nano urea is over 80%, whereas 40% is for conventional (Gupta, 2022). Nano-scale fertilizers demonstrate improved nutrient transportation and delivery through plasmodesmata, micro-channels that link cells at the nanoscale (Mahanta et al., 2019).

IFFCO, also acknowledged as the Indian Farmers' Fertilizer Cooperative Limited, has led the way in developing Nano Urea, which symbolizes a significant advancement in overcoming the limitations associated with conventional urea application. Furthermore, Studies have shown that the use of nano urea can lead to a reduction in greenhouse gas emissions and reduce nitrogen leaching and runoff, which can have harmful effects on aquatic ecosystems (Upadhyay et al., 2023).

According to the information from the producer, it is similar to one bag of urea with 4% nitrogen in a nanoscale structure. LNU can substitute half of the urea granules utilization. (Kumar et al., 2020) So, keeping a 50% basal dose of urea before transplanting, IFFCO nano urea may be applied after 20-25 days of transplanting in two splits of spray. The total demand for urea in FY 2022-23 is about 26 lakh MT (Ministry of Agriculture, 2023). In that case, Bangladesh needs to import 16 lakh MT of conventional Urea besides 10 lakh MT of domestic production. Keeping 50% of demand, about 13 lakh MT can be replaced by only 13,000 MT (2,60,00,000 bottles) of nano urea.

Researchers got the significant effect of IFFCO Nano Urea in different climatic conditions. In this regard, several studies have been done to evaluate the efficiency of nano urea in Bangladesh. The researcher found a significant effect of nano urea on different crops. By Implementing nano urea, the govt. Subsidy can be minimized.

This study endeavor seeks to offer practical recommendations for individuals who are keen on implementing nano urea in agricultural systems, particularly considering its novelty within the agricultural landscape of Bangladesh. Through collaborative efforts and interdisciplinary approaches, the sustainable use of nano urea can contribute to the advancement of modern agriculture and the achievement of food security goals in Bangladesh. Furthermore, it possesses the ability to save both time and money, while also ensuring environmental safety.

Evaluation of Nano Urea on Different Crops in Bangladesh

Liquid nano urea effect on black gram -*Vigna mungo* L.

The study examined the efficiency of black gram (*Vigna mungo* L.) treated with various nitrogen sources, including nano urea, at the experimental field of the Bangladesh Institute of Nuclear Agriculture (BINA) substation. The highest grain yield was obtained with nano urea foliar spray, resulting in a substantial increase in yield (1587.33 kg) compared to control (983.33kg) and traditional fertilizer practices (1439.67 kg).

Within the research, the application of nano urea through foliar spray at critical growth stages exhibits a significant improvement in plant height (cm), number of main branches per plant, number of pods per plant, number of seeds per pod, 100-seed weight (g), and crop yield (kg/ha) compared to both the control and conventional agricultural practices. The study found that foliar application of nano urea significantly increased black gram yield compared to farmers' practices or control, suggesting further research for more convenient results (Islam et al., 2023).

Nano fertilizer for slow and sustainable release of micronutrients

Empirical evidence has shown the gradual and enduring dispersion of essential nutrients into the soil and water by using urea-modified hydroxyapatite and nanoparticles such as copper, iron, and zinc. The presence of nutrients in the ladies' finger plant was confirmed, and the physicochemical properties of the fertilizer were found to be improved compared to commercial fertilizer. Researchers got significant results on *A. esculentus*. To keep the environment safe, slow-release fertilizers can sustainably release nutrients that are needed.

Nano fertilizers have demonstrated positive impacts on enhancing soil fertility, mitigating nutrient depletion, and enhancing agricultural productivity. The utilization of nanoparticles in the field of agriculture plays a fundamental role in fostering robust plant development. Researchers have inferred that nano fertilizers have significant benefits as plant nutrients, such as gradual and enduring nutrient discharge, minimal application rates (50 mg/week), cost-effectiveness, nutrient-dense produce, and negligible environmental pollution (Tarafder et al., 2020).

Climate-smart and resilient rice production practices in the MFS

The study focuses on implementing climate-smart agricultural practices using nano-fertilizer applications to ensure sustainable agricultural development and productivity. The collaboration between the Bangladesh

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Rice Research Institute (BRRI) and the SI-MFS initiative aims to test the suitability of direct-sided rice (DSR) in the cropping systems of the Northern area of Bangladesh. Additionally, the paper discusses the use of nano-fertilizers as a possible alternative to traditional fertilizers, which can reduce nutrient leaching and volatilization losses, exhibit controlled release of nutrients, and have a lower cost compared to conventional fertilizers.

The study was conducted in multiple locations (Gazipur, Kushtia, and Rangpur districts). There were eight treatments. Among them, 50% RDN (Recommended Dose of Nitrogen) and 4 ml Nano Urea with two sprays got the significant result. The research reflects the significant performance of nano-urea in reducing overall N fertilizer and farmers' production costs in rice (Ahmed et al., 2023).

Evaluation of Nano Urea on Different Crops: Worldwide Scenario

The effect of foliar application on rice

Spraying liquid nano urea at critical growth cycle stages improved crop production. It provided the required nutrition for crops, leading to the saving of mineral nitrogen fertilizers and decreased accumulation of nitrogen in the surroundings with 12-16% higher yield in rice.

Using the nano urea increased nutrient uptake, improved soil bioavailability, and enhanced the ability to provide required nutrition at critical stages of the crop growth cycle. The use of nano urea as a foliar spray improved crop production and provided the required nutrition for crops, leading to the saving of nitrogen fertilizers to the extent of 25-34%. Spraying nano urea in low-input rainfed conditions can save mineral N and decrease N accumulation, while liquid nano fertilizers can provide necessary nutrition for crops, improving crop production (Velmurugan et al., 2021).

Nano fertilizer substitute for conventional urea

Liquid nano-urea demonstrates enhanced nutrient use efficiency and decreased environmental contamination, making it a viable alternative to traditional urea. In the experiment, 50% N and two doses of nano urea spray were given to the wheat at a developmental stage 4580 kg/ha), maize (5150 kg/ha), chickpea (2133 kg/ha), and mustard (2750 kg/ha). All the crops showed a significant effect in yield compared to farmers' fertilizer practice, where 100% N was applied through conventional urea (Lakshman et al., 2022a).

Nano fertilizers for sustainable crop production

The unique characteristics of nanomaterials, such as their small size and high surface area-to-volume ratio, allow for better absorption and utilization of nutrients by plants. IFFCO has conducted multi-location-multi-crop trials in India to evaluate the efficacy of these nano fertilizers and ensure that the harvested produce is safe for consumption. Due to the significant increase in surface area, the effectiveness of their work was enhanced. At the critical growth stage, two to three splits of application are found to be effective.

Rice: The highest level of productivity was achieved through the application of 50% nitrogen in combination with 100% phosphorus and potassium, along with two applications of Nano nitrogen, resulting in a yield of 5.30 ton per hectare.

Maize and Millet: The utilization of nano urea and nano Zn in combination with 50% of the recommended amount of conventional urea and zinc sulphate is an effective solution for enhancing crop growth and achieving optimal yield.

Cotton: A 23% increase in crop yield was documented through the application of 50% nitrogen, 100% phosphorus and potassium, along with two applications of nano urea.

The utilization of nano urea on crops such as rice, wheat, maize, tomato, cucumber, and capsicum resulted in a 50% decrease in the usage of traditional urea fertilizer. Furthermore, it led to an enhancement in crop yield within the range of 3-23% for wheat, 5-11% for tomato, 3-24% for paddy, 2-15% for maize, 5% for cucumber, and 18% for capsicum.

Nanotechnology provides benefits in terms of size, shape, quantity and effectiveness of formulations at the nano-scale, enabling precise and gradual delivery of agricultural inputs to fulfill crop nutritional needs without disrupting agricultural ecosystems (Kumar et al., 2021).

Effect of nano urea with different fertilizer doses on the productivity of rice - *Oryza sativa* L.

The interaction effect between nano urea and fertilizer application significantly influenced the biological yield, straw yield, and grain yield of rice. The significant effect of nano urea and fertilizer application was recorded on the number of panicles per hill (11.03), panicle length (23.49cm), no. of grains per panicle (152.4), and test weight (30.23 g) of rice applying 8 ml nano urea 20 DAT and 40 DAT. In addition, grain yield (5611 kg per ha), straw yield (7236 kg per ha), biological yield (12847 kg per ha), and harvest index (43.76%) were significant. In the research, applying the same dose of nano urea N content in grain (1.10%) and straw (0.65%), protein content in grain (6.90) and N use efficiency 8.04 kg per kg. The results were similar to the treatment of 4 ml nano urea 20 DAT and 40 DAT (Kumar et al., 2023).

The efficiency of nano urea: 500 ml equal to 50 kg granular urea

A 500 ml bottle of Nano-urea is deemed comparable to a 45 kg bag of urea fertilizer, offering a cost reduction of 10% compared to a traditional urea bag (Lakshman et al., 2022b), which itself is 10% cheaper than another traditional urea bag and A single nano-sized urea liquid particle possesses a diameter of 30 nanometers, exhibiting a surface area to volume ratio that is 10,000 times greater than that of conventional granular urea (Kumar et al., 2023).

Generally, a 50 kg urea bag (Bangladesh) contains 46% of nitrogen, whereas the total amount of nitrogen is (50x0.46) 23 kg. Plants can uptake 30-35% of nitrogen (Raun & Johnson, 1999). So, the total nitrogen uptake by plants is (23x0.30) 7.5 kg from conventional urea fertilizer.

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On the other hand, the average size of urea aggregate is 10,000 nm for prilled urea, and the average size of nano urea aggregate is only 25 nm (Bhadu et al., 2023). So, (10,000/25) one prilled urea aggregate is equivalent to 420 nano urea aggregate.

According to the calculation, under 90 % use efficiency (c), a 500 ml bottle has (0.2x90) 18 grams of nitrogen. So, the nitrogen use efficiency is equivalent to (420x18.0) 7500 grams or 7.5 kg for IFFCO nano urea, which is equivalent to a 50 kg conventional urea bag.

Effect of nano urea on soil and environment

Regarding greenhouse gas (GHG) emissions and energy consumption. In the synthesis stage of urea production, GHG emissions are significant, averaging 2.68 tons of CO_2 per ton of urea produced. This accounts for about 81.3% of the total GHG emissions over the entire life cycle of urea production. Additionally, the average life cycle energy consumption (LcEC) for urea production is around 30.1 gigajoules (GJ) per ton. This energy consumption results in CO2 equivalent emissions totaling approximately 2.41 tons of CO2 per ton of urea (Shi et al., 2020).

Efforts to reduce these emissions and improve energy efficiency could be crucial in mitigating the environmental footprint of urea production. Using nano urea, 50% of conventional urea may be replaced, and it can reduce GHG emissions by about 50%, according to the data. The slow release and increased efficiency of Liquid Nano-Urea results in reduced run-off and leaching, which helps maintain soil health and minimize the adverse impact on the environment (Tomar et al., 2023).

Chemical composition (Nano Biotechnology Research Center, IFFCO, 2023)

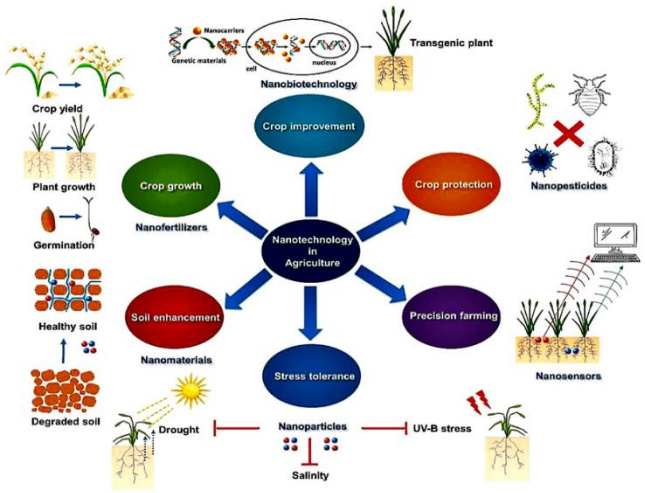
Table 1. As per the Nano Biotechnology Research Center of IFFCO, liquid nano urea contains the below components

Parameter	Value
Total Nitrogen (% by weight)	4.0
Physical Particle Size (TEM)	28.72 nm
Hydrodynamic Particle Size (DLS)	33.80 nm
Zeta Potential (mV)	+37.50 mV
Viscosity (cPs)	6.90
pH	4.55

Working principle of Nano Urea

LNU is composed of Nanoscale nitrogen particles accounting for 4%. These particles exhibit a diminutive size ranging from 20 to 50 nm, resulting in a larger surface area and a higher density of particles per unit area compared to traditional urea. The Nanoparticles possess the capability to efficiently infiltrate through the cell wall or leaf stomatal pores. Subsequent to their ingress into the plant, they are mobilized to other plant components via phloem cells and plasmodesmata, with a diameter of 40 nm.

They can attach to carrier proteins using aquaporin, ion channels, and endocytosis mechanisms. Following their penetration, these nanoparticles distribute to plant regions necessitating nitrogen and discharge nutrients in a regulated manner, thereby mitigating environmental wastage. The application of Nano-urea in plants amplifies metabolic processes and fosters meristematic activities, culminating in heightened apical growth and an expanded leaf photosynthetic area. The cumulative impact of these activities ultimately results in increased yields and diminished nitrogen deficiency within plant systems (Lakshman et al., 2022c).



Source: Iqbal et al., 2022

Figure 1. Nanoparticle distribution Flow Chart for LNU

Future Prospects of Liquid Nano-Urea as a Fertilizer Substitute

Trend of Organic Farming

The world is experiencing a growing trend towards organic farming. Liquid Nano Urea (LNU) fits the bill, making it an excellent alternative for farmers looking to shift towards organic farming.

Increasing Demand

The use of nanoparticles for agriculture production is increasing globally, and Liquid Nano Urea is expected to play a major role in providing sustainable crop solutions in the future.

Research and Development

Research and development of more accessible and cheaper production methods for nanoparticles are being carried out, thereby reducing the cost of producing Liquid Nano-Urea and improving its availability in the market.

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Table 2. Comparison between liquid nano urea and conventional urea (Lakshman et al., 2022d)

Characteristics	Nano urea	Conventional urea
1. Year of Invention	2021	1823
2. Technology	Nanotechnology	Conventional method
3. Particle size	32 nm	1 mm
4. Use efficiency (%)	85-90	30-40
5. Storage area requirement	Small area	Large area
6. Pollution	No	Air, water and soil
7. Vaporization	No	Yes
8. Soil residual	No	Yes
9. Effect on soil	Enhance quality	Acidifies soil
10. Availability in plant	Throughout the life cycle	3-4 days
11. Effect on crop maturity	Maturity on time	Early maturity
12. Intake medium	Direct through leaves	Through roots
13. Method of use	Only for foliar spray	Soil application as basal and top dressing and foliar spray

CONCLUSION

Urea fertilizer is strategically important to ensure the food security of the rising population in Bangladesh. However, against this backdrop, the use of Nano Urea (liquid) has emerged as a ground-breaking innovation. Indian Farmers' Fertilizer Cooperative Limited (IFFCO) introduced the first-ever Nano Urea. It is a ground-breaking innovation for future agriculture. Failure to introduce a urea-saving technology might threaten the urea economy and food security in Bangladesh. LNU is a ground-breaking innovation for future agriculture. A 500 ml bottle is sufficient to cultivate one acre of rice, saving 90% on the cost of urea. Failure to introduce a urea-saving technology might threaten the urea economy and food security in Bangladesh.

Recommendations

Research should be done to evaluate the effect of Nano Urea on environment and plant nutrient analysis.

Conflict of Interest

There are no conflicts of interest mentioned by the authors.

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