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Nanotechnology Based Nano Urea to Increase Agricultural Sustainability

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Introduction

The world's growing population poses significant challenges for global agriculture to meet the increasing demand for food production. It is predicted that by 2025, there will be 8 billion people on the planet, and by 2050, there will be 9 billion. It is commonly accepted that in order to feed this fast-expanding global population, agricultural production must rise (Sekhon., 2014). In this context, fertilizers play a crucial role in enhancing crop yields and ensuring food security. Among fertilizers, urea, a nitrogen-containing compound, is one of the most widely used due to its high nitrogen content and affordability. However, traditional urea fertilizers have inherent limitations, such as inefficient nutrient uptake and losses, which can lead to environmental pollution and economic inefficiencies. To address these challenges, researchers and scientists have turned to nanotechnology to develop innovative solutions for agriculture. Nano urea, a nanoscale form of conventional urea, has emerged as a potential game-changer in the field of fertilizers. By manipulating the particle size and structure of urea at the nanoscale, nano urea aims to overcome the limitations of traditional urea and revolutionize nutrient management practices in agriculture. The US Environmental Protection Agency has defined "Nanotechnology" as the field of research that deals with the study and management of materials at dimensions of approximately 1-100 nm (Dhewa., 2015). Nano urea, also known as nanoscale urea or nanotechnology-based urea, is a type of urea fertilizer that has been formulated at the nanoscale level. Urea is a commonly used nitrogen fertilizer

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in agriculture, providing essential nutrients to plants for their growth and development. Traditional urea is in granular form, but with advancements in nanotechnology, researchers have explored ways to modify the structure of urea to enhance its efficiency and effectiveness as a fertilizer. Nano urea is produced by breaking down urea particles into nanoscale dimensions, typically ranging from 1 to 100 nanometers. Nano urea's smaller particle size increases its surface area significantly compared to conventional urea. This larger surface area can improve the rate of nutrient release and absorption by plant roots, potentially leading to better nutrient utilization and reduced nutrient losses through leaching and volatilization. The nanoscale structure of urea allows for the controlled release of nitrogen over an extended period. This controlled release feature helps to supply nitrogen to plants more gradually, matching their nutrient demands during various growth stages. Due to its improved uptake and reduced losses, nano urea has the potential to increase nutrient use efficiency, meaning a higher percentage of the applied fertilizer is utilized by plants, resulting in reduced environmental impacts and cost savings for farmers. By improving nutrient uptake and reducing nitrogen losses, nano urea has the potential to lower the risk of nutrient runoff and leaching into water bodies, which can contribute to environmental issues like eutrophication. Leading contributors to environmental degradation and climate change have been leaching and gaseous emissions of nutrients from agricultural areas (Kumar et.al 2021). It is essential to note that nano urea is still a developing technology, and its widespread adoption and commercial availability may vary from region to region. Before using any new agricultural product, including nano urea, it is crucial to consider its specific benefits and potential risks and follow recommended application rates and guidelines.

IFFCO Nano Urea

In September 2021, IFFCO (Indian Farmers Fertiliser Cooperative Limited) has developed a product called "IFFCO Nano Urea." It is a nanotechnology-based urea fertilizer that aims to enhance nutrient efficiency and reduce the environmental impact of traditional urea fertilizers. The IFFCO Nano Urea (figure 1) is formulated

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using nanotechnology to reduce the particle size of urea, resulting in nano-sized urea particles. This nanoscale urea offers several potential benefits, including increased nutrient use efficiency, controlled-release properties, and reduced nitrogen losses compared to conventional urea.

The first nano fertilizer in the world is IFFCO nano urea (liquid). The FCO 1985, GOI, has informed them. It has 4% nitrogen overall. The size of nano nitrogen particles ranges from 20 to 50 nm. The availability of N to the plant is improved by the high utilization efficiency (>80%) of the nano urea. It penetrates through stomata and other holes when sprayed on plant leaves during crucial growth phases and is absorbed by the plant cells. Phloem transport is used because it is disseminated throughout the plant from source to sink wherever it is needed. Application of nano urea in rice, wheat (figure 2), barley, maize, sorghum, pearl millet, pulses, vegetables and fruits etc.

Time and method of application

Mix 2-4 ml nano urea (4% N) in one liter of water and spray on crop leaves at its active growth stages.

For best result 2 foliar spray:

- 1st spray at active tillering/ branching stage (30-35 days after germination or 20-25 days after transplanting).
- 2nd spray 20-25 days after 1st spray or before flowering in the crop.

Note- Don't stop using the base nitrogen that is given by DAP or complex fertilizer. Only remove the top dressed ures that have been applied in 2–3 splits. Depending on the crop, its longevity, and general conditions, the amount of nano urea that is sprayed can be raised or decreased.

Safety and precaution

The nano urea non-toxic, safe for the user, safer for flora and fauna but it is recommended to use face mask and gloves while spraying on the crop. Store in a dry place avoiding high temperature and keep away from the reach of children and pets.

General instruction before use

- The nano urea bottle shakes well just before use for proper mixing.
- The spraying by knapsack sprayer (figure 3) which has flat fan or cut nozzles for uniform spray throughout the crop canopy.

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- The spray is avoiding during early morning and late evening.
- The spray is repeated again if rainfall occurs within 12 hours of spray.
- It is 100% complete water-soluble fertilizer and compatible agrochemicals, it can be easily mixed with different bio stimulants.
- For better result it should be used within 12 months from manufacturing date.

Key features and potential advantages of IFFCO nano urea may include:

- **Enhanced nutrient use efficiency:** The nanoscale structure of IFFCO Nano Urea provides a larger surface area, improving nutrient uptake by plant roots. This leads to enhanced nutrient use efficiency, as a higher proportion of the applied nitrogen is utilized by crops, reducing wastage and losses.
- **Controlled-release properties:** IFFCO Nano Urea is designed to release nitrogen gradually over time. This controlled-release feature ensures that nutrients are supplied to plants as needed, matching their growth stages and optimizing nutrient availability.
- **Environmental sustainability:** By reducing nitrogen losses, such as leaching and volatilization, IFFCO Nano Urea can help minimize environmental pollution and mitigate the negative impacts of excessive nitrogen in the ecosystem.
- **Cost-effectiveness:** While nanotechnology-based products can initially have higher production costs, the improved efficiency and reduced fertilizer application rates associated with IFFCO Nano Urea may lead to cost savings for farmers in the long run.
- **Adaptability to different crops:** IFFCO Nano Urea is designed for use in various crops, making it suitable for a wide range of agricultural practices.

Advantages of nano urea

Nano urea offers several advantages and potential benefits over traditional urea fertilizers. Some of the key advantages of nano urea include:

- **Increased NUE:** Nano urea's nanoscale structure provides a larger surface area, which enhances its contact with plant roots. This improved contact facilitates better N uptake by plants, leading to increased N use efficiency. A higher percentage of the applied nitrogen is utilized by crops, reducing wastage and potential environmental pollution.

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- **Slow and Controlled release of nitrogen:** One of the significant advantages of nano urea is its controlled-release properties. Conventional urea releases nutrients rapidly, which can result in nutrient leaching and volatilization. In contrast, nano urea can gradually release nitrogen over an extended period, synchronizing nutrient supply with crop demand at various growth stages. This controlled-release feature ensures a more consistent and efficient nutrient supply to plants.
- **Enhanced crop productivity:** Due to its improved nutrient uptake and controlled-release properties, nano urea has the potential to enhance crop productivity. Plants receive a steady supply of nitrogen, leading to better growth, increased yields, and improved overall crop quality.
- **Reduced environmental impact:** Nano urea's controlled-release nature and increased nutrient use efficiency help reduce nitrogen losses to the environment. It minimizes the risk of nutrient leaching into groundwater and runoff into water bodies, which can cause eutrophication and other environmental issues. By mitigating nitrogen losses, nano urea contributes to more sustainable agricultural practices.
- **Lower fertilizer application rates:** The enhanced efficiency of nano urea allows farmers to apply lower quantities of fertilizer to achieve the same or even better results compared to traditional urea. This reduction in fertilizer application rates can lead to cost savings for farmers and also reduces the potential for over-fertilization.
- **Improved soil health:** The controlled-release properties of nano urea can contribute to maintaining soil health and reducing soil degradation caused by excessive nutrient leaching. By providing a steady nutrient supply, nano urea helps preserve soil fertility and minimizes nutrient imbalances.
- **Potential for targeted delivery:** Nanotechnology offers the possibility of targeted delivery of nutrients to specific plant tissues or root zones. This could enable precise nutrient delivery based on a plant's growth stage or specific nutritional needs, optimizing plant growth and resource utilization.
- **Integration with other agricultural inputs:** Nano urea can be formulated to be compatible with other agrochemicals and fertilizers, facilitating its integration into existing agricultural practices. Farmers can potentially mix nano urea with other inputs, enhancing their overall efficacy.

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- **Adaptability to different crops:** Nano urea's versatility makes it suitable for various crops, allowing farmers to use it in a wide range of agricultural systems and geographical regions.

It is important to note that while nano urea shows great promise, continued research and field trials are essential to validate its effectiveness, safety, and long-term impacts on crops, soils, and the environment. Additionally, regulatory frameworks and guidelines must be established to ensure responsible and safe use of nano urea in agriculture.

Nano Urea Treated Wheat field

Disadvantages of nano urea:

While nano urea holds promise for improving nutrient management in agriculture, it is essential to acknowledge its potential drawbacks and demerits. Some of the main demerits of nano urea include:

- **Environmental concerns:** Despite claims of reduced environmental impact, the potential risks associated with nano urea need careful consideration. The long-term

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effects of nano-sized particles on soil ecosystems and non-target organisms are not yet fully understood. There is a possibility that nanoparticles may accumulate in the soil or leach into water bodies, raising concerns about their environmental persistence and potential toxicity.

- **Health and safety risks:** As with any nanotechnology-based product, concerns about the safety of nano urea for human health exist. Inhalation or direct exposure to nanoparticles during manufacturing or application could pose risks to farmers, agricultural workers, or consumers. Proper safety measures and risk assessments are crucial to ensure safe handling and use of nano urea.
- **Cost and affordability:** Nano urea, being a technologically advanced product, might be more expensive to produce than conventional urea. The higher production costs could result in higher prices for farmers, limiting its accessibility, particularly in developing regions where affordability is a significant concern. Farmers' willingness to adopt nano urea may depend on its cost-effectiveness compared to traditional fertilizers.
- **Regulation and standardization:** The regulation of nanotechnology-based agricultural products, including nano urea, remains a challenge. The lack of comprehensive standards and regulations specific to nano urea could lead to uncertainties regarding its safety, environmental impact, and proper usage. The development of appropriate guidelines and oversight is essential to ensure responsible and safe application.
- **Limited research and knowledge gap:** Despite ongoing research, there is still a considerable knowledge gap regarding the long-term effects of nano urea on soil health, plant growth, and ecosystem dynamics. More research is needed to fully understand the potential consequences of using nano urea, especially over extended periods and in diverse agricultural settings.
- **Nanoparticle behaviour:** Nano-sized particles can behave differently from their bulk counterparts due to unique physicochemical properties. These differences might affect the release rate, mobility, and uptake of nutrients by plants. The behaviour of nano urea in different soil types and environmental conditions requires careful investigation.

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- **Compatibility and mixing:** Nano urea might require specific handling and application methods, and there could be compatibility issues when mixed with other agrochemicals or fertilizers. Ensuring that nano urea is compatible with existing agricultural practices is vital for its successful integration into farming systems.

Challenges

While nano urea holds tremendous promise, several challenges and considerations warrant attention:

- **Safety and toxicity:** As with any nanotechnology-based product, the safety and potential toxicity of nano urea need thorough evaluation. Research must ensure that nano urea does not pose risks to human health, the environment, or non-target organisms.
- **Long-term effects:** The long-term effects of using nano urea on soil health, plant growth, and ecosystem dynamics require extensive investigation. Sustainable agriculture calls for products that maintain soil fertility and biodiversity over time.
- **Cost and accessibility:** The widespread adoption of nano urea depends on its cost-effectiveness and accessibility to farmers, particularly in developing regions. Manufacturing and distribution processes need to be optimized to make nano urea economically viable for farmers.
- **Regulations and standards:** The development of appropriate regulations and standards is crucial to govern the production, marketing, and use of nano urea. These regulations will ensure that the product meets safety requirements and contributes positively to sustainable agriculture.

Conclusion

Nano urea represents a promising advancement in the field of agriculture and fertilizer technology. With its increased nutrient use efficiency, controlled-release capabilities, and potential to reduce environmental impacts, nano urea offers a pathway towards more sustainable and productive agricultural practices. However, to fully harness its benefits, ongoing research and collaboration between scientists, policymakers, and industry stakeholders are essential. Addressing safety concerns, understanding long-term effects, optimizing manufacturing processes, and establishing appropriate regulations will be key in

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realizing the full potential of nano urea and promoting a sustainable future for global agriculture.

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