

Fertilizing the future:

Nano solutions for sustainable agriculture

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To meet the growing food demands driven by an increasing global population, a substantial rise in crop production is essential. Although conventional fertilizers play a vital role in enhancing agricultural yields, they are often associated with environmental concerns, limited nutrient use efficiency and significant nutrient losses. In response, nano fertilizers have surfaced as a promising solution, presenting enhanced efficiency, and reduced environmental footprints. Nano fertilizers boost superior properties such as enhanced nutrient uptake efficiency, controlled release modes, leading to amplified crop yields, quality, and sustainability. They also facilitate precision farming, reduce input costs, and offer logistical advantages. Case studies comparing nano urea and nano DAP with conventional fertilizers counterparts underscore their efficacy and cost-effectiveness. Application methods and cost considerations further underscore the possibilities of nano fertilizers in revolutionizing agriculture towards a more sustainable and productive future.

Keywords: Conventional fertilizers, Nano fertilizers, Sustainable, Yield

Increasing global food demands necessitate a 70% rise in crop production, urging the adoption of fertilizers for enhanced yields and soil preservation. In this endeavour, the indispensable utilization of fertilizers has emerged as a fundamental practice for enhancing crop yields and conserving soil fertility. To achieve this, conventional fertilizers must be largely used. Nevertheless, traditional fertilizers, upon application to fields, undergo uptake by plants, degradation, runoff, leaching, volatilization, and photo-decomposition, resulting in low nutrient use efficiency around 30–45% for nitrogen, 18–20% for phosphorus, and 35–40% for potassium. Present conventional fertilizers exhibit suboptimal nutrient absorption efficiency and are associated with significant losses, leading to adverse environmental repercussions. Despite a plethora

of approaches for developing efficient and eco-friendly fertilizers, nano fertilizers have emerged as a promising solution to tackle these challenges by offering heightened efficiency and mitigated

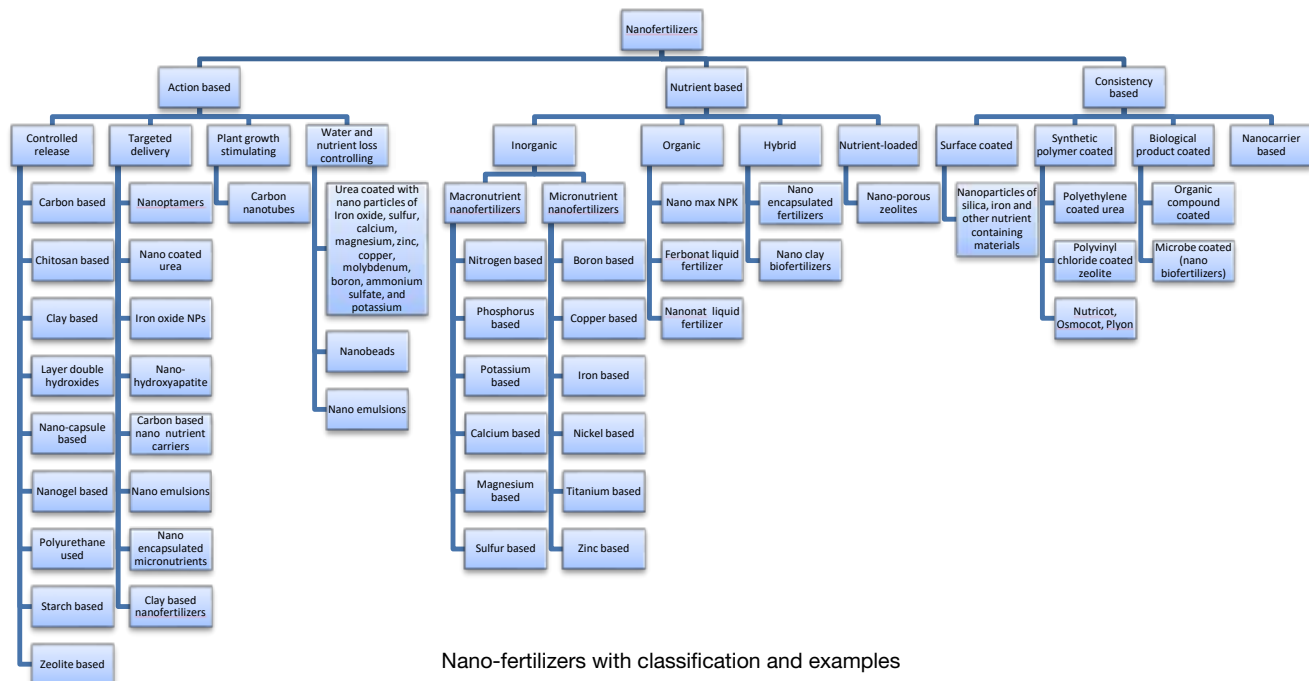
environmental impacts (Table 1.).

Other major advantages of nano fertilizers

Increased crop yield and quality: Applied in low concentrations, nano fertilizers have demonstrated

Table 1. Performance comparison of nano and conventional fertilizer approaches

Properties	Nano fertilizers	Conventional fertilizers
Nutrient uptake efficiency	Augments fertilizer utilization efficiency and the ratio of plant nutrient uptake, thus economizing on fertilizers.	Less efficacious due to the poor absorption of its bulk composites by plants.
Control release modes	Encapsulation, coupled with a coating of polymer resin, sulfur and waxes, facilitates precise control over the release of nutrients.	Excessive release provokes toxicity and undermines ecological balance.
Solubility and dispersion of nutrients	Enhances the solubility and dispersion of insoluble mineral constituents in soil, rendering them more bioavailable to plants.	Less accessible to plants owing to decreased solubility and larger particle size.
Effective duration of release	Improves and extends the plant's nutrient acquisition rate	During delivery, nutrients required by plants are forfeited as insoluble salts.
Low rate of fertilizer needed	Reduces nutrient losses resulting from drift, leaching and drift.	Substantial amounts of fertilizers are dissipated through runoff, leaching and drift.



Nano-fertilizers with classification and examples

the ability to enhance crop growth, increase yields and improve the quality of agricultural produce, while also promoting plant health and overall productivity.

Precision farming: Nano fertilizers offer opportunities for precision agriculture, allowing for more targeted and efficient application of nutrients. This can lead to reduced waste, improved resource management, and increased overall efficiency in agricultural operations.

Potential for sustainable agriculture: Nano fertilizers offer a sustainable approach to agriculture by decreasing the reliance on excessive fertilizer usage. They can enhance nutrient use efficiency and significantly reduce the environmental impact of agricultural activities.

Price advantage: They cost less than the subsidized conventional fertilizers resulting into lower input cost for the farmers.

Logistics and warehousing: They are easy to carry and store thus, they are economical in terms of reduced transportation and warehousing cost.

Economic benefit due to additional crop yield: Application of nano fertilizers results into better crop productivity and higher income for the farmers. Enhancement in

total factor productivity (TFP) of our crop production systems.

Nano urea: An efficient alternative to traditional urea

- Its unique small size (20–50 nm) increases availability of nitrogen to crop by $\geq 80\%$
- As it fulfill nitrogen requirement it increases photosynthesis, root-shoot biomass and there by increases number of tillers and branches
- Improves the nutritional quality of crop
- Better benefit cost ratio with less input cost
- Easy to store and transport because of its compact size (500 ml bottle of nano urea is better over urea bag weighing 45 kg)



Nano DAP: An efficient alternative to traditional DAP

- Particle size of < 100 nm which enables to enter easily inside the seed/root surface or through stomata of leaf and other openings.
- They are functionalized with bio-polymers and other excipients.
- Its enhanced spread ability

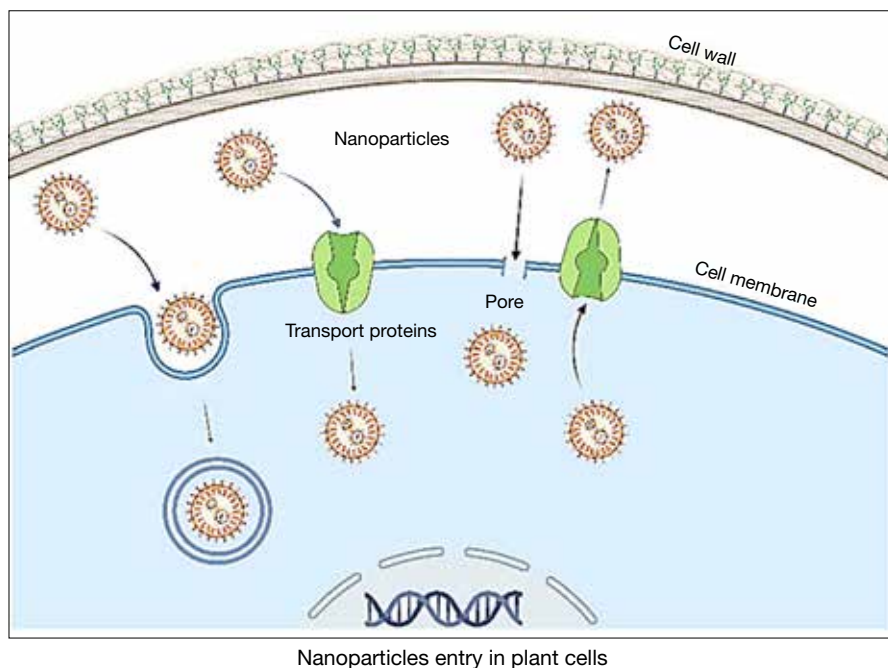
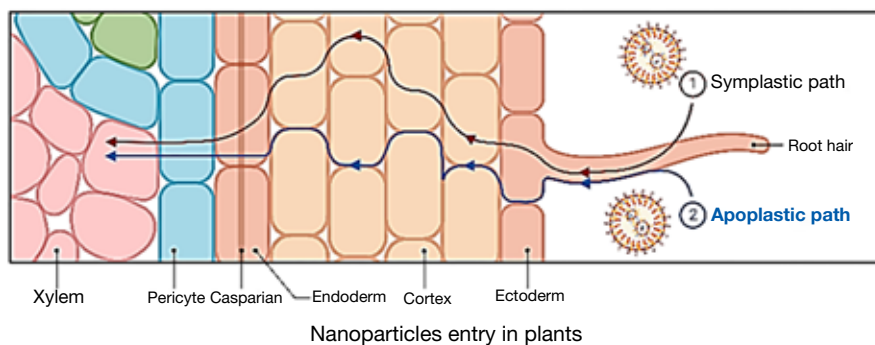
and efficient assimilation within the plant system make nano fertilizer effective as a seed primer, promoting early germination, improved seed vigor, increased chlorophyll content, and higher crop yield and quality.

- Precision and targeted application fulfills nutritional requirement of crop without harming the environment and bio safe.
- Has nutrient use efficiency $> 90\%$
- Cheaper and economical for farmers, easy to store, warehouse and transport.

Mechanism of nano fertilizers

The sustained nutrient release of nano fertilizers helps maintain consistent nutrient availability for plants, thereby supporting improved growth. This effect is largely due to their nano-scale particle size and large surface area, which allow easier penetration through root and leaf pores. As particle size decreases, the specific surface area and particle density increase, enhancing contact with plant surfaces and significantly





- Stored in a cool place
- Keep away from children and pets
- Use within 24 months from the date of manufacturing
- Nano DAP can be applied as seed treatment, seedling dipping and foliar application.
- If rain occurs within 12 hours of spray, it is advised to repeat the spray

Table 2. Types of sprayer used in application

Nano Urea	Nano DAP
Knapsack Sprayer	Knapsack Sprayer
Boom Sprayer	Power Sprayer
Drone Sprayer	Drone Sprayer

Effect on plants

Nitrogen supplied through fertilizers undergoes complex transformation processes such as biological nitrogen fixation, humus mineralization, immobilization, and nitrification in acidic soils, while denitrification and volatilization are predominant in alkaline conditions. These dynamic pathways make nitrogen management challenging and hinder efforts to optimize nitrogen use efficiency. In recent years, numerous strategies have been explored to enhance nitrogen utilization in crops, with nanotechnology emerging as a promising tool to transform nutrient management in agriculture.

Nano-fertilizers contributes in physiological and biochemical processes of crops by increasing the availability of nutrients, which help in enhancing metabolic processes and promoting meristematic activities causing higher apical growth and photosynthetic area. It was observed that foliar spraying of nano N increased the growth attributes due to enhanced availability of nutrients through easy penetration of nano N through stomata of leaves via gas uptake. This effect may result from the ability of nano fertilizers to improve the solubility and dispersion of otherwise insoluble nutrients, thereby increasing their availability to plants. This is attributable to the heightened efficacy of plant biology, culminating in more proficient nutrient absorption.

improving nutrient uptake efficiency and overall nutrient content in plants.

Nano urea is the advanced version of urea of particle size 20–50 nm, brings about high surface area of roughly 10,000 times over 1 mm urea capsule. This large surface area and small size makes it advantage by penetrating better and fulfills nutrient requirement and moreover nano urea is produced in green and sustainable technology. It is said that, 500 ml of nano urea can replace 5 kg bag of urea which will help farmer in transporting and also in spreading of fertilizer. Application of nano urea not only yield better crop yield, but also enhances soil quality.

India nano urea market has reached around 14 million litres in FY 2022 and is expected to hike at an impressive compound annual growth rate (CAGR) of 29.34% during the forecast period until FY 2032, because in FY 2022, IFFCO has

been the lone producer of nano urea, but to fulfil the needs of increasing crop production National Fertilizers Limited and Rashtriya Chemicals and Fertilizers are coming up with new nano urea manufacturing plants.

Method of application of nano urea and nano DAP

Recommended dose of nano urea is 2–4 ml in 1 L of water (or) 500 ml bottle per 1 acre of field. It is applied as two foliar sprays, 1st spray at active tillering or branching stage (or) 30–35 days after germination or 20–25 days after transplanting and 2nd spray at 20–25 days after 1st spray or one week before flowering in crop (Table 2.). Best application time is preferably during morning (9–11 AM) and evening (3–6 PM) hours.

Precautions

- Recommended to use face mask and gloves

Cost of nano fertilizers sprayers and how it is cost effective?

Cost of the manual sprayers varies from ₹1,200–1,500/sprayer, battery operated sprayers from ₹3,000–4,500/ sprayer and power sprayers from ₹6,000–10,000/sprayer. Further, the cost of spray of nano fertilizer per acre would be in the range of ₹200–250 only. IFFCO is also coming up with agriculture drone spraying model at block level and is also training village youth for providing these services to farmers on custom hire basis thereby generating youth employment in rural area.

Co-operative societies/FPOs/dealers also provide spraying services on custom hire basis. Besides, IFFCO has been facilitating 1 lakh sprayers spraying services to the farmers through its retail points on mutually acceptable basis. It is expected that drone machine would be available on mutual

basis to farmers who wish to spray nano fertilizers. Forming standard operating procedure (SOP) for use of drone to spray nano fertilizers in agriculture is also under consideration.

Spraying nano fertilizers through drip irrigation is not possible as fertilizer through drip irrigation (fertigation) are applied on soil. In this context, nano fertilizers could be sprayed by use of sprinklers but not through drip irrigation. Manual spray of nano fertilizers is harmful to the hands, skin and eyes of the farmers, while use of drone would eradicate practice of manual spraying of nano-fertilizers as drone works like a robot who needs the direction of the farmer.

SUMMARY

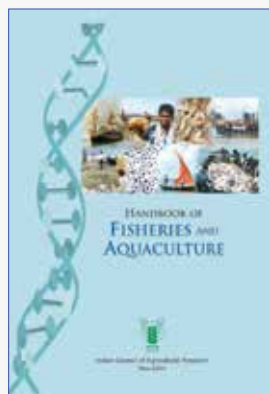
The utilization of nano fertilizers is gaining attention as a viable solution to overcome the limitations of conventional fertilizers in

addressing the growing demands of global food production. With superior nutrient uptake efficiency, controlled release modes, and enhanced solubility, nano fertilizers offer a pathway towards sustainable agriculture, precision farming, and environmental conservation. Moreover, their economic benefits, including lower input costs and reduced transportation expenses, underscore their potential to revolutionize agricultural practices while addressing food security concerns. As nanotechnology continues to advance, nano fertilizers stand poised to play a crucial role in optimizing nutrient use efficiency, enhancing crop productivity, and fostering ecological sustainability in the agricultural sector.

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HANDBOOK OF FISHERIES AND AQUACULTURE

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In 2006, the Indian Council of Agricultural Research, brought out the First Edition of 'Handbook of Fisheries and Aquaculture'. The present revised edition comprises 42 updated and six new chapters, viz. Fish physiology; Aquaculture engineering, Fisheries development in India; Fisheries cooperatives; Demand and supply of fish; and Climate change - impact and mitigation. The Handbook would be of great value to students, researchers, planners, farmers, young entrepreneurs and all stakeholders in fisheries and aquaculture.

TECHNICAL SPECIFICATIONS

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