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Nano-Fertilizers: The Future of Efficient and Eco-Friendly Farming in India

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Nano-fertilizers are a new and modern type of fertilizer developed with the help of nanotechnology. They contain nutrients in the form of extremely small particles, ranging in size from 1 to 100 nanometers (1 nanometer = 10^{-9} meters). These tiny particles are easily and quickly absorbed by plants. Nano-fertilizers release nutrients slowly, which prevents them from being wasted through leaching into the soil or drifting away in the air. This not only increases crop yield but also causes less harm to the environment.

In India, Nano Urea is primarily being used, while the development and testing of other nano-fertilizers like Nano DAP, Nano Zinc (Zn), Copper (Cu), and Sulfur (S) are ongoing. For example, a 500 ml bottle of Nano Urea costing ₹240 can be as effective as 45 kg of conventional urea (₹267). Demonstrations on crops have shown that nano-fertilizers can increase yield by 8% to 22%. The use of nano-fertilizers began in India in 2021 and is now growing rapidly.

In 2024-25, the Indian Farmers Fertilizer Cooperative Limited (IFFCO) sold 365 million bottles, which is 47% more compared to the previous year. However, currently, Nano Urea accounts for only about 3.36% of the total urea production, and Nano DAP makes up approximately 5.04% of the total DAP production.

India aims to replace 2.5 million tonnes of conventional urea with Nano Urea (Table: 1), which could save approximately ₹20,000 crore in subsidies every year. Overall, nano-fertilizers are proving to be an effective option that is economical for farmers, environmentally safe, and capable of increasing agricultural productivity.

Indian Context – Challenges and Opportunities

Agriculture in India feeds over 1.4 billion people and provides livelihood to millions of rural families. However, today, agriculture is facing multiple challenges. The biggest among them is soil degradation. Due to excessive use of chemical fertilizers, improper farming techniques, and lack of organic matter in the soil, nearly 30% of India's land has deteriorated. Another major issue is nutrient imbalance. Farmers use a large amount of urea every year, but plants are able to effectively absorb only 30% to 50% of it. The rest goes to waste, polluting both soil and water. In addition, nearly 80% of India's freshwater is used in agriculture, leading to increasing water scarcity.

Table 1: IFFCO's Nano Fertilizer Production and Expansion Details

Production	Details
Start Dates	Nano Urea – June 2021 Nano DAP – April 2023
Manufacturing Plants	6 Nano Urea plants (capacity ~2.662 billion bottles/year) 4 Nano DAP plants (~1.074 billion bottles/year)
Sales in FY 2024-25	365 million bottles sold (47% increase from previous year) – Nano Urea + Nano DAP 268 million bottles – Nano Urea 97 million bottles – Nano DAP (Equivalent to 1.2 million tonnes of urea and 4.85 lakh tonnes of DAP)
Market Penetration	Nano Urea: 3.36% of total urea consumption Nano DAP: 5.04% of total DAP consumption
Future Product Plans	Nano NPK (granular), Nano Zinc, and Nano Copper products

In this context, nano-fertilizers have emerged as a promising solution for efficient nutrient delivery and cost reduction in farming. These fertilizers release nutrients slowly and in a targeted manner, minimizing waste. For instance, nano urea developed by the Indian Farmers Fertiliser Cooperative Limited (IFFCO) enables plants to absorb about 80–90% of nitrogen, compared to only 30–40% with conventional urea. Studies by institutions like TERI and IFFCO indicate that nano-fertilizers can increase crop yields by 8–22%, while reducing the need for conventional fertilizers by nearly half. Additionally, their storage and transportation are more economical and convenient. At a time when farming costs are rising and environmental challenges are intensifying, nano-fertilizers offer a sustainable and practical alternative.

Research, Development, and Commercialization

India is one of the leading countries in the development and use of nano-fertilizers. Much of the credit goes to IFFCO, which has developed and commercialized nano fertilizers like Nano Urea, Nano DAP, and Nano Phosphorus. Research institutions such as The Energy and Resources Institute (TERI) have played a vital role in scientific research, impact assessment, and field trials.

TERI's studies have shown that nutrient use efficiency of nano-fertilizers can be as high as 80–90%, while traditional fertilizers offer only 30–50% efficiency. As a result, farmers may be able to use 25–50% less fertilizer, leading to lower costs and reduced environmental impact (see Table 2).

IFFCO's nano-fertilizers have received safety and quality approvals from various Indian government agencies such as the Department of Biotechnology (DBT) and the Fertiliser Control Order (FCO). These approvals have authorized their sale across India and confirm that nano-fertilizers are safe for crops, soil, and the environment. Thus, nano-fertilizers are emerging as a significant technological innovation for sustainable and cost-effective agriculture in India.

Government Policy and Promotional Efforts

The Government of India has formally recognized nano-fertilizers like Nano Urea and Nano DAP under the Fertilizer Control Order (FCO). This ensures the quality and safety of these fertilizers and enables their widespread use in agriculture. A major initiative in this direction is the National Campaign for Balanced and Efficient Fertilizer Use, led by the Indian Council of Agricultural Research (ICAR). The campaign aims to encourage farmers to use fertilizers in a scientific, balanced, and smart manner—nano-fertilizers being an integral part.

Table 2: Results of Nano-Fertilizer Trials by TERI

Parameter	Results (Nano-Fertilizers)	Comparison (Conventional Fertilizers)
Nutrient Use Efficiency	Over 90%	30%–50%
Fertilizer Requirement	25%–50% less	Full amount required
Crop Yield	Increase of 8%–22%	Normal
Environmental Impact	Low (reduced pollution, safer water sources)	High (soil and water pollution)
Storage and Transportation	Easy and economical	Bulky and expensive
Nutrient Delivery to Plants	Fast and efficient (slow, targeted release of nutrients)	Less efficient (significant nutrient loss)
Impact on Soil Quality	Improves soil quality	Deteriorates soil quality

To increase awareness, the government is using tools such as rural camps, street plays, exhibitions, and educational films in local languages to inform farmers about nano-fertilizers, precision farming, and other modern technologies. Nano-fertilizers are now being made available in rural areas through PM Kisan Samriddhi Kendras (PMKSKs). Efforts are also underway to make drones, battery-operated sprayers, and other advanced tools accessible to farmers. Notably, under the "NaMo Drone Didi" scheme, women self-help groups (SHGs) are being provided with drones, promoting women empowerment and technological inclusion.

However, financial support or subsidies for nano-fertilizers are currently limited. Several experts and policymakers have recommended that these products be included under the Production Linked Incentive (PLI) scheme to boost their production and adoption.

Benefits of Nano-Fertilizers

Nano-fertilizers offer multiple benefits to Indian farmers. The most significant advantage is their high Nutrient Use Efficiency (NUE). For instance, Nano Urea developed by IFFCO has a NUE of approximately 80–90%, compared to 25–50% for conventional urea. This means that plants receive more nutrition with less waste.

Nano-fertilizers are also easier and cheaper to store and transport. A 500 ml bottle of Nano Urea (costing around ₹240) is considered as effective as a 45 kg bag of conventional urea (priced around ₹267). This significantly reduces logistics and labor costs, ultimately lowering the overall cost of cultivation for farmers (see Table 3). Field trials have shown that the use of nano-fertilizers can increase crop yields by 8% to 22%, which leads to improved

farmer income. They are also environmentally beneficial, as nano-fertilizers release nutrients slowly and in a controlled manner, reducing nitrogen leaching, soil degradation, and water pollution.

Some advanced nano-formulations are even referred to as "smart fertilizers", as they can deliver not only nutrients but also pesticides or bio-stimulants. This reduces the dependency on chemical fertilizers and pesticides, helps conserve natural resources, and lowers greenhouse gas emissions—making nano-fertilizers a sustainable solution to combat climate change.

Challenges, Concerns, and Criticisms

Despite the many benefits of nano-fertilizers, there are several challenges to their acceptance and use in India:

1. Lack of awareness among farmers remains the biggest hurdle. Many farmers are not fully convinced about the benefits, usage methods, and impact of nano-fertilizers, making them reluctant to switch from conventional fertilizers. This highlights the urgent need for education and training programs.
2. Cost of spraying equipment is another issue. Sprayers can cost anywhere between ₹1,200 and ₹10,000, which becomes an economic burden for small and marginal farmers. Although drones offer a modern solution, their high cost (₹8–10 lakhs) and operational complexity limit their accessibility.
3. Health and safety concerns are also emerging. Scientists are still studying the long-term impacts of nano-fertilizers on human health, soil biodiversity, and the ecosystem. Some studies have raised concerns about possible disruption of soil microbial life and biological imbalances.
4. There is inconsistency in field trial results. While some trials show positive effects on crop growth, others report no significant change or even reduced yields, raising questions about the reliability of nano-fertilizers.
5. Regulatory frameworks are still evolving. Though some approvals have been granted under the Fertilizer Control Order (FCO), there is a pressing need for comprehensive monitoring and quality control systems for manufacturing, storage, distribution, and usage.
6. Controversies in some states have further fueled skepticism. For example, in Rajasthan, farmers alleged they were forced to buy Nano Urea. Similarly, a two-year field study by Punjab Agricultural University (PAU), Ludhiana in 2020–21 and 2021–22 found a 21.6% drop in wheat yield and a 13% decline in paddy yield after using Nano Urea. It also noted a reduction in protein content in the grains—by 11.5% in wheat and 17% in paddy. The study highlighted that Nano Urea was nearly 10 times more expensive than conventional urea, resulting in financial losses for farmers.

Following these criticisms, the Government of India issued a circular in July 2025 stating that no farmer should be forced to purchase Nano Urea. However, effective implementation on the ground and policy adjustments based on farmers' feedback are still needed.

Table 3 – Impact of Nano Urea on Crops

Key Point	Impact
High Efficiency	Nitrogen absorption by plants increases to 80–90%
Lower Quantity Required	Just 1 bottle (500 ml) per acre replaces 45 kg of conventional urea

Increase in Yield	On average, 8–10% increase in crop production
Improves Soil Health	Reduces nitrogen overload and protects soil microorganisms
Environmentally Friendly	Reduces pollution and greenhouse gas emissions
Cost-Effective	Lowers fertilizer costs for farmers

Future Opportunities and Roadmap

The future of nano-fertilizers in India appears promising. Leading fertilizer company IFFCO is developing new products like Nano NPK, Nano Zinc, and Nano Copper to meet the diverse nutritional needs of crops. Countries like Brazil, Kenya, the USA, Slovenia, Mauritius, Zambia, Nepal, and Bangladesh have also shown interest in nano-fertilizers, lending global recognition to the technology.

Experts believe that India should: Invest more in research, Develop clear regulatory frameworks, and Ensure affordable access and training for farmers. Innovations such as precision farming, bio-compatible nano-fertilizers, and smart fertilizers—which combine nutrients with pesticides or bio-stimulants—could further enhance their effectiveness. It is essential to ensure small farmers have access to these technologies and to maintain continuous monitoring to safeguard health and the environment.

Conclusion

Nano-fertilizers can help Indian agriculture by improving nutrient use efficiency, reducing pollution, and lowering dependence on chemical fertilizers. Institutions like TERI and IFFCO have played a vital role in their development, while government initiatives have supported awareness and distribution.

However, for safe and widespread adoption, India must:

1. Improve farmer education, especially for smallholders.
2. Make spraying equipment more affordable and accessible.
3. Promote independent and long-term research.
4. Establish clear laws to ensure quality and safety.
5. Encourage evidence-based, voluntary use without pressuring farmers.

If these steps are implemented effectively, nano-fertilizers could become a strong foundation for sustainable growth in Indian agriculture.

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