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# Nano-Fertilizers for Urban Vegetable Farming: A Sustainable Pathway for Smart Cities

**Aurobinda Behera* and Akash Kumar Parida**

**Department of Vegetable Science, College of Agriculture, Odisha University of Agriculture and Technology (OUAT), Bhubaneswar 751003, Odisha, India**

## INTRODUCTION

Urban farming is rapidly gaining importance as Indian cities struggle with rising populations, food demand and limited cultivable land. Traditional fertilizer use in urban vegetable production often leads to inefficiency, nutrient leaching and environmental pollution. Nano-fertilizers such as nano-urea, nano-zinc and nano-iron developed by Indian research institutes and companies, provide a novel solution for precise nutrient delivery, higher efficiency and eco-friendly cultivation. When integrated with hydroponics, vertical farming and rooftop vegetable production, nano-fertilizers can significantly enhance yield, nutrient use efficiency and quality of vegetables while reducing chemical loads in urban environments. This article highlights the principles, applications, benefits, challenges and future prospects of nano-fertilizers in urban vegetable farming, emphasizing their role in achieving smart and sustainable cities.

***Keywords:*** Nano-fertilizers, Urban farming, Hydroponics, Smart cities, Vegetable crops

### 1. Introduction

India's urban population is projected to exceed 600 million by 2036 (MoHUA, 2021), placing immense pressure on cities to secure nutritious and fresh food. Urban farming methods—such as rooftop farming, vertical farming and hydroponics—have emerged as key solutions for localized vegetable production. However, efficient nutrient management remains a challenge in such systems due to space constraints, limited soil quality and environmental pollution risks. Conventional fertilizer use often leads to nutrient losses of 50–70% in nitrogen and 80–90% in micronutrients (FAO, 2022). To overcome these challenges, nano-fertilizers have been introduced as a smart alternative. Developed by ICAR-IARI and IFFCO, products like Nano

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Urea (20,000 ppm N), Nano Zinc (ZnO 4–6 nm) and Nano Iron have shown promising results in improving nutrient uptake, yield and soil health (Prasad, 2023).

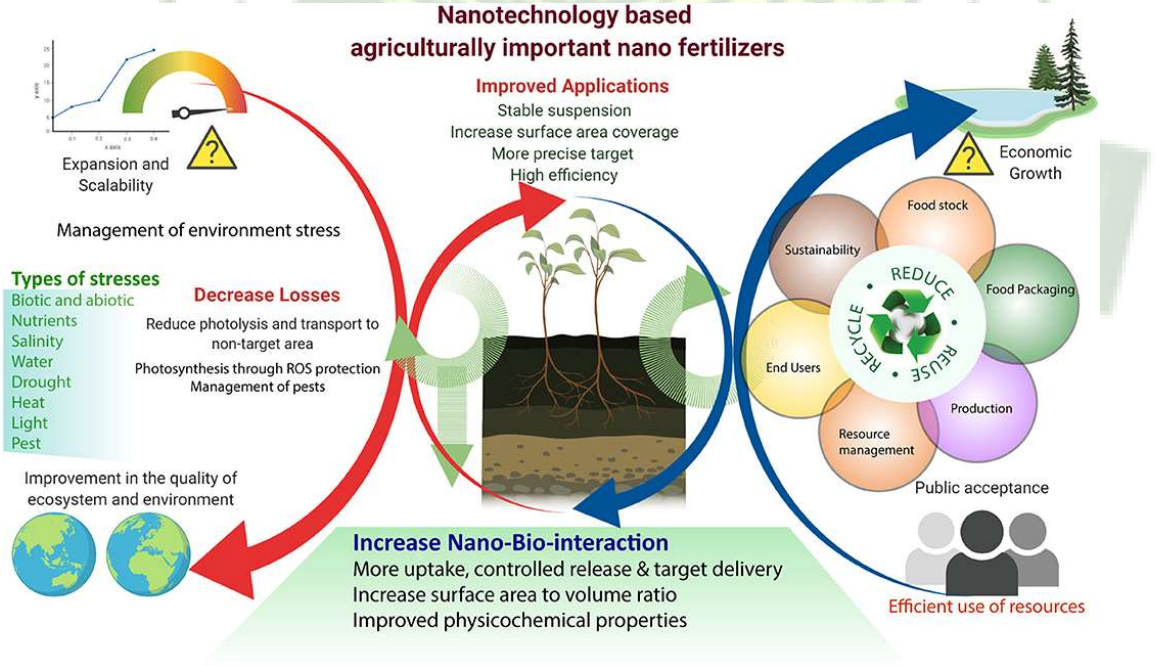
The integration of nano-fertilizers into urban vegetable systems is now gaining momentum, aligning with India's initiatives such as the Smart Cities Mission and the PM-PRANAM scheme, which promote sustainable input use.

**2. What is Nano-Fertilizers?**

Nano-fertilizers are nutrient formulations engineered at **1–100 nm particle size**, which enhances their solubility, reactivity and absorption in plants. They can be applied as foliar sprays, seed treatments or nutrient additives in hydroponic solutions.

**Key advantages include:**

- **Higher nutrient-use efficiency (NUE):** Nano urea provides equivalent benefits to conventional urea at only **one-tenth the dose**.
- **Controlled release:** Nutrients are released slowly, reducing leaching and volatilization.
- **Targeted delivery:** Nano-particles penetrate leaf stomata and root tissues more effectively.
- **Eco-friendly:** Reduces chemical fertilizer burden and pollution in cities.




**3. Application in Urban Vegetable Production Systems**

**(a) Hydroponics**

Nano-fertilizers can be integrated into nutrient solutions, reducing the requirement for large volumes of salts. This minimizes clogging in pipes and ensures uniform nutrient availability to leafy greens like spinach, lettuce and basil.

**(b) Vertical Farming**

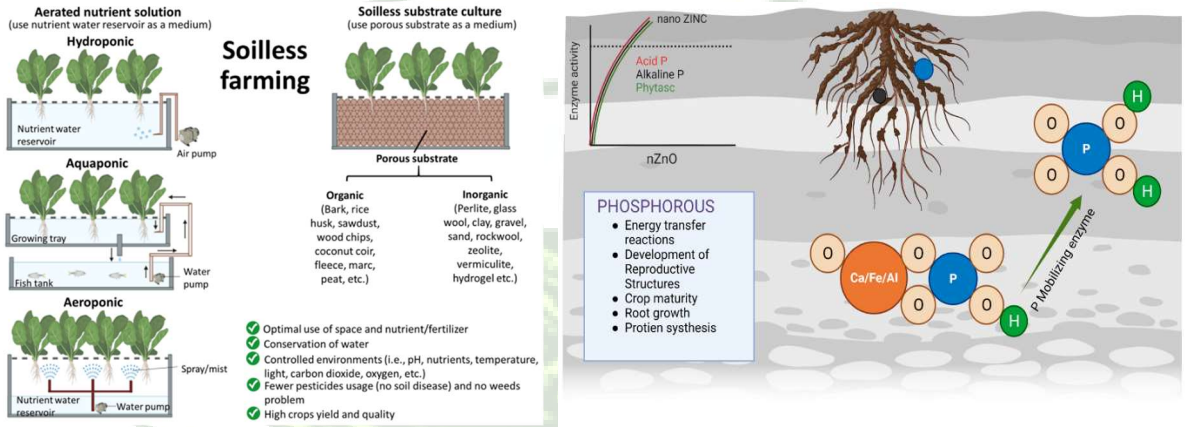
Vertical farming relies on precise nutrient dosing. Nano zinc and nano iron improve photosynthetic efficiency, leading to faster growth cycles in crops like tomato, chilli and cucumber.

**(c) Container & Balcony Gardening**

Urban households often face leaching losses in pots and containers. Foliar sprays of nano-fertilizers provide a sustainable solution for higher productivity with minimal fertilizer inputs.

**(d) Rooftop Polyhouses**

Nano-fertilizers reduce the environmental footprint of rooftop farms by lowering chemical runoff and enabling safer vegetable production for local consumption.




**4. Research Evidences in Vegetables**

Several studies in India confirm the potential of nano-fertilizers in vegetables:

- **Tomato:** Foliar application of nano-urea improved fruit set, yield by **15–18%** and total soluble solids (IARI, 2022).
- **Chilli:** Nano-zinc sprays enhanced flowering and fruit quality while reducing disease susceptibility (Mishra *et al*., 2023).
- **Spinach & Amaranthus:** Nano-iron application increased chlorophyll content and micronutrient density by **20–25%** (Patra *et al*., 2022).
- **Cucumber:** Combined nano-urea and nano-zinc application improved fruit yield and water-use efficiency (Singh *et al*., 2023).

These results suggest that nano-fertilizers are not only yield-enhancing but also contribute to improved nutritional quality of vegetables.

**5. Benefits of Nano-Fertilizers in Urban Systems**

a) **Reduced fertilizer use:** One 500 ml bottle of nano urea can replace a 45 kg bag of conventional urea (IFFCO, 2021).

b) **Minimized pollution:** Lower leaching and runoff in urban ecosystems.
c) **Higher productivity:** 10–20% increase in vegetable yields reported in trials.
d) **Nutrient-rich produce:** Enhanced micronutrient density improves urban nutrition.
e) **Cost-effectiveness:** Suitable for small-scale growers and urban households.
f) **Climate-smart:** Contributes to reduced greenhouse gas emissions from fertilizer use.

**6. Challenges:**

Despite their promise, several challenges must be addressed:

a) **Regulatory frameworks:** Clear guidelines are needed to ensure quality and prevent spurious products.
b) **Safety assessment:** Long-term impacts of nanoparticles on soil, water and human health must be studied.
c) **Awareness gaps:** Many urban farmers are still unaware of nano-fertilizer use.
d) **Standardization:** Dosage optimization for different vegetables and systems is required.
e) **Integration with technology:** IoT-based nutrient monitoring can complement nano-fertilizer use for precision farming.

**Future Thrusts:**

- Expanding pilot projects in smart cities.
- Public-private partnerships for affordable supply.
- Linking nano-fertilizers with **hydroponics kits** and **urban farming models**.
- Policy incentives to encourage adoption in rooftop and vertical farms.

**7. Conclusion**

Nano-fertilizers represent a revolutionary innovation in nutrient management for urban vegetable production. Their integration with hydroponics, vertical farming and rooftop cultivation not only improves yield and quality but also ensures sustainability by reducing input costs and environmental pollution. With India's rapid urbanization, nano-fertilizers can play a vital role in creating climate-smart, resource-efficient and self-reliant cities. Future research, awareness campaigns and policy support will be critical in scaling up this technology and making Indian cities leaders in sustainable urban agriculture.

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