
POPULAR ARTICLE

Nano plant breeding advancements

R. K. Yelutala

ICAR- Indian Institute of Oilseeds Research, Rajendranagar, Hyderabad- 500 030 Telangana, India

Corresponding authors email: rohanyelutala2000@gmail.com

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Nano plant breeding, or nano-osmics, is an advanced field that merges nanotechnology with plant science to develop superior crops by manipulating materials at the atomic scale, using nanoparticles as precise delivery vehicles for genes, nutrients, and growth regulators to enhance traits like yield, stress tolerance, and nutritional value, essentially enabling "atomic engineering" of plants for faster, more targeted genetic improvement than traditional methods.

How it works

Smart delivery: Nanoparticles (1-100nm) act as carriers for DNA, hormones, or nutrients, delivering them directly into plant cells with high precision, something traditional breeding struggles with.

Gene editing and transformation:

Nanomaterials facilitate more efficient gene delivery for genome editing (like CRISPR) and stable genetic transformation, allowing precise DNA modification to introduce desirable traits.

Phytohormone modulation: Nanoparticles can interact with plant hormone pathways (auxins, cytokinins) to regulate root growth, shoot development, and stress responses.

Nano-fertilizers and pesticides: Nano-sized fertilizers release nutrients slowly, improving

uptake and reducing runoff, while nano-pesticides offer targeted pest control, enhancing efficiency and minimizing environmental impact.

Molecular tools: Nano-sensors help monitor plant health and stress conditions at the cellular level, guiding breeding decisions.

Key benefits and applications

Accelerated breeding: Speeds up the development of improved varieties by targeting specific genetic changes quickly.

Enhanced traits: Develops crops with better yield, nutritional content (e.g., more vitamins), and resistance to drought, pests, and diseases.

Sustainable agriculture: Improves input efficiency (fertilizers, water) and reduces reliance on harsh chemicals, leading to less pollution.

Seed treatment: Priming seeds with nanoparticles to make them more resilient and self-sufficient from the start.

Genetic engineering: Enabling precise control over gene expression and transfer.

Stress management: Creating plants that better withstand adverse conditions like salinity or drought. Nano plant breeding advancements leverage nanotechnology for precise nutrient delivery, efficient

gene editing, and stress tolerance enhancement, using nanoparticles as carriers to deliver genes/drugs, nano-sensors for monitoring, and nano-formulated fertilizers/pesticides for targeted action, leading to higher yields, reduced chemical use, and resilient crops for sustainable food security, though potential environmental impacts need careful study.

Key advancements

Nano-enabled gene editing: Nanoparticles (like carbon nanotubes) efficiently deliver DNA/RNA (including CRISPR components) into plant cells, bypassing cell walls for precise genetic modification, creating disease-resistant or drought-tolerant varieties faster.

Smart nano-delivery systems: Nanocarriers (nano-fertilizers, nano-pesticides) precisely deliver nutrients (like zinc, copper) or protectants (fungicides) directly to plant tissues, improving uptake, reducing waste, and minimizing environmental pollution.

Stress management: Nanoparticles modulate phytohormone signaling (auxins, gibberellins) to enhance tolerance to drought, salinity, and heavy metals, improving plant survival and yield under harsh conditions.

Nano-sensors and diagnostics: Fluorescent nanosensors embedded in plants or applied to soil detect stress (pathogens, nutrient deficiency) early, signaling via smartphone apps for timely intervention.

Seed Priming: Nanoparticles improve seed germination, seedling vigor, and early growth, leading to better crop establishment.

Impact on breeding

Accelerated breeding: Precise gene delivery shortens development cycles for improved cultivars.

Enhanced crop quality: Better nutrient delivery boosts nutritional content and yield.

Sustainable agriculture: Reduces reliance on bulk chemicals, promoting eco-friendly practices.

Challenges and future

Toxicity: Concerns exist regarding long-term soil/water effects and potential plant toxicity from certain nanoparticles.

Regulation: Regulatory frameworks are still evolving.

Future: Integrating nano-genomics and advanced diagnostics will further refine breeding for climate-smart agriculture and greater food security.