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Advances in Nano Technology for Fruit Crops

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Abstract

Nanotechnology represents a rapidly advancing multidisciplinary field that integrates principles from physics, chemistry, biology, materials science, mechanical engineering and computer science to manipulate matter at the nanoscale level (1–100 nm). At this dimension, materials exhibit unique structural, optical, mechanical and biochemical properties that can be strategically exploited to revolutionize agricultural and horticultural systems. In plants, nanoparticles interact at cellular and molecular levels influencing physiological, biochemical, and morphological processes depending on their size, surface chemistry, reactivity, composition and dose. Nanotechnology has wide range of benefits in the field of horticulture by increasing the biological effects of nano particles on higher plants to attain self-sufficient production. Nano fertilizers or nano encapsulated nutrients have properties to release nutrients effectively when it is applied at lower amounts that regulate the plant growth and enhance target activity. These nano fertilizers are more efficient, decreasing soil pollution and other environmental risks that occurs while using common fertilizers. Inorganic nano materials like silver NPs have a good anti-microbial property and so widely used along with edible films and packaging materials to enhance the shelf life of fruits. In pest control, nano pheromones play significant role in control of pests with high efficiency, shelf life and ecofriendly management. It has the potential to provide novel and improved solutions to many grand challenges face by Indian agriculture and the society today and in the future.

Keywords: Nano technology, Nano biosensors, Nano encapsulation, Nano Fertilizers.

Introduction

Nanotechnology is an emerging and revolutionary field of science that deals with the manipulation, synthesis and application of materials at the nano meter scale, typically ranging between1–100 nm. At this ultra-small dimension, materials exhibit novel physical, chemical, mechanical, optical and biological properties that differ significantly from their bulk counterparts. The term nanotechnology was coined by Professor Norio Taniguchi of Tokyo Science University in 1974 to describe the precision of the industrialized biomaterials at the nano meter level. In the agricultural sector, nanotechnology has emerged as a powerful tool to address major global challenges such as increasing food demand, declining soil fertility, nutrient losses, climate change. In fruit crops, nano technology holds immense potential due to the high value, perishability and quality sensitivity of fruits. Nano-based inputs such as nano fertilizers, nano pesticides, nano herbicides and nano biosensors ensure efficient nutrient delivery, targeted pest and disease management, improved stress tolerance, enhanced fruit quality and yield, while minimizing environmental contamination. Smart and intelligent packaging systems based on nano sensors can monitor freshness, detect spoilage gases, and ensure food safety for consumers. Similarly, nano-encapsulation techniques enable controlled and slow release of agrochemicals ensuring precision agriculture with minimal wastage. However, alongside its benefits, careful evaluation of nano particle toxicity, biosafety, environmental

impact and regulatory frame works is essential to ensure safe and responsible application. With continuous research advancements, nanotechnology is set to revolutionize fruit science and pave the way toward smart, efficient and eco-friendly horticultural systems.

Nano Technology Concept

- Concept first introduced by American physicist **Richard P. Feynman** called as father of nanotechnology, **"There's Plenty of Room at the bottom" (1959).**
- The term Nanotechnology was coined by **Nori Taniguchi** from the Tokyo Science University in 1974. Popularized by Eric Drexler in Molecular Nanotechnology.

Nanotechnology Definition:

- Nano is a prefix derived from the Greek word for dwarf.
- Nanotechnology is the art and science of manipulation matter at nanoscale.
- Nanoscience is the study of the fundamental principles of molecules and structures with dimension between at least 1nm to100 nm by controlling shape and size.

Nanomaterials improve nutrient use efficiency, promote physiological and biochemical processes in plants, and support healthier growth with reduced chemical load. Moreover, nanotechnology has a remarkable role in postharvest management of fruits, where nano-coatings, nano-packaging, silver nanoparticles, nano-films, and nano composite materials are being used to extend shelf life, reduce microbial spoilage, delay ripening, maintain firmness, enhance appearance, and retain nutritional quality.

Research findings across various fruit crops such as mango, strawberry, citrus, guava, apple and berries have demonstrated significant improvements in germination, growth, yield attributes, storage stability and market value through nanotechnology interventions. Thus, nanotechnology represents a promising frontier for sustainable fruit production by enhancing productivity, profitability and quality while safeguarding environmental health.

Properties of Nano Particles:

- Melting Point
- Diffusivity
- Mechanical Properties
- Thermal Properties
- Electrical Properties
- Magnetic Properties
- Catalytic Properties
- Optical Properties

Application of Nano Technology in Fruit Crops:

- Nano Encapsulation
- Nano Fertilizers
- Plant Protection
- Seed Technology
- Weed Management
- Post harvest Management

Nano Encapsulation:

It is the coating of various substances over nano scale material to release their active ingredient in controlled manner**.** They are,

- Quick release
- pH release
- Moisture release
- Heat release

Example

- Slow release of fertilizers achieved by the encapsulation of KNO3 in graphene oxide film.
- Graphene oxide is used for targeted and controlled delievery of chalogenic pesticide which achieving more than 35% larval mortality.

Nano Fertilizer in Fruit crops

- Slow and steady release of nutrients.
- Helps timely delivery and targets the root zone. Improving fertilizer use efficiencies.
- High surface area.
- Reduce the frequency of fertilizers application

Plant Protection in Fruit Crops

- Conventional crop protection practices involve applications of large scale and overdose of fungicides, insecticides that affects soil fertility and environment stability.
- Nano sensors for early detection of pests &diseases.
- Smart and controlled delivery of nano formulation.
- Eco-friendly and prevents residue development in soil.

Seed Germination in Fruit Crops:

The germination of seeds is a sensitive phase in life cycle of plant, which facilitates seedling development, survival and population dynamics.

Weed Management in Fruit Crops

- Weed enables the crop loss of more than 40% as compared to another environmental factor.
- Out of annual consumption of 2 million tons of pesticide herbicide share 47.5%.
- Conventional Herbicide – Non target specific, Contamination of soil and water bodies and development of herbicides - resistant weed.
- Nano herbicides for enhancing use efficiency.
- Less herbicide is required to achieve the desired weed reduction.
- Highly target specific, controlled release and kill the underground parts of weeds.

Post Harvest Management

Most of the fruits are highly perishable in nature and have very limited storage life. About 40 % of produce in tropical countries lost in post-harvest handling.

By use of Nanotechnology tool

- Controlling Growth and Development of Microorganisms.
- Improving strength, Quality and Packaging Beauty.
- Introducing a new Generation of Packaging Coverage's (films).
- Increasing the shelf life of a product.

For Example, Silver nano particles (AgNPs) are widely used to post harvest treatment of fruit because of its antimicrobial and anti-bacterial content.

- Improved packaging
- Active Packaging
- Intelligent Packaging

Nano Biosensors

Conventional farming

Smart farming

Any device that is capable of conveying data and evidence about the behavior and characteristics of NPs at the nanoscale level to macroscopic level.

Need for Real time tracking of crop

- Measuring and monitoring tree growth and development
- Detection and diagnosing
- Nutrient deficiency, toxicity and pesticide residue

Nanotechnology used

- Nano sensor
- Nanotechnology-based GPs
- Supercomputer
- Remote sensing

Nano particles for fruit yield

The effect of different concentrations of iron and zinc oxide nano particles for the yield characters of strawberry cv. Chandler and they noticed that treatment ZnO NP's 150ppm+ FeO NP's 150ppm recorded significantly a greater number of fruits/plant (32.27), higher yield(478g/plant) and total fruit yield (5.97t/ha) compare to other treatments.

Nano fertilizers for fruit yield &quality

The response of foliar application of Zinc (Zn) and boron (B) nano fertilizers on pomegranate (*Punica granatum* cv. Ardestani) and reported that maximum fruit yield (18.5Kg/tree) and number of fruits(95.9/tree) were observed in treatment Zn60+B6.5mg/Lit where as maximum fruit diameter(78.8mm), fruit length(91.6mm), fruit weight (291.9 g), TSS(17.06%), total sugar (14.93/100 g)and antioxidant activity(29.44 %) were recorded with treatment Zn 120 + B 6.5 mg/Lit.

Nano packaging for fruit quality

The effect of nano packaging on preservation of Chinese jujube and they found that nano packaging showed minimum weight loss, fruit decay percentage, browning rate, increased firmness compared to normal packaging.

Nanogel pheromones for post control

That nanogel pheromone showed the better attraction of fruit flies and long-lasting shelf life compared to the methyl eugenol alone when tested in fruit flies of guava.

Nano clay coating for post-harvest quality

The effect of carnauba wax-nano clay emulsion coatings on Valencia orange fruits for improving the post-harvest quality. The treatment with carnauba waxes 1% nano-clay showed reduced weight loss and increased the sensory quality of fruits.

Conclusion

From foregoing discussion, it can be concluded that nanotechnology plays a vital role in increasing yield attributes of fruits. Nano fertilizers improve fruit yield and quality more efficiently and decreases soil pollution. Nano coating and nano packaging improve the shelf life of fruits, delays ripening, maintains freshness with other quality parameters and silver NP's having antimicrobial properties too. Nanogel pheromone traps are good for fruit flies with ecofriendly pest management. Nano-clay coating helps in sustainable postharvest management by preserving sensory and nutritional quality of the commercial fruits.