Nano Technological Approaches in Horticulture

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In order to increase crop output and ensure the food security of the world's growing population, plant nutrition is essential. Pesticide and chemical fertilizer applications are the foundation of any agricultural economy. Nanotechnology is the most recent advancements for sustainable agriculture. The use of nanotechnology in horticulture and agriculture is currently very common. The factor affecting fruit trees that has been the subject of the most research and development is nano fertilizers (NFs), which are crucial for enhancing vegetative growth, reproductive growth, and flowering, which increases productivity, improves product quality, and ultimately lengthens shelf life and reduces fruit waste. These nanomaterials that are often sprayed on trees at low concentrations over a period of time and in multiple sessions are also regarded as growth promoters. Because nanoparticles have unique physicochemical properties, such as a large surface area, high reactivity, and tuneable pore size, nanotechnology opens up a wide range of innovative uses in the plant nutrition disciplines to meet future demands of the growing population (Pandey et al., 2021).

Applications of nanotechnology in horticulture

According to Singh and Ratanpal (2014), the quantity of waste produced by horticultural products is projected to be between 20 and 30 percent in developing nations. If we can cut this number by just 5 to 10%, enormous savings will be realised. In a location wherein per capita consumption is just half of the recommended level, reducing these losses could both increase farmer incomes and stimulate higher consumption of this very nutritious fruit. The best way to solve this issue is to use cutting-edge technologies like biotechnology and nanotechnology in products to improve production efficiency and reduce post-harvest waste. The management of supply chain operations related to the quality of food, handling, packaging, and safety has already benefited from the use of nanotechnology. Through improvements in agri-food production, processing, preservation, and packaging, the application of nanotechnology in the field of agricultural supply chains is already delivering potential benefits to farmers, the food business, and consumers alike (FAO/ WHO, 2010)

Role nanomaterials on growth and development of horticultural Crops

Solid colloidal particles known as nanoparticles are made up of macromolecular substances. The use of nano fertilizers, which promote extremely effective plant nutrition and are environmentally friendly, increases agricultural output. Nano fertilizers are given to the plants gradually, precisely, and effectively. For instance, according to Prasad et al. (2012), ZnO nanoparticles increase the yield of peanuts (Arachis hypogaea). Nano fertilizers are used in horticulture to boost flower fertility, pollination, and vegetative growth, which increases fruit tree productivity and improves product quality (Zagzog et al. 2017). Similar to this, spraying nano-boron on mango tree leaves has been shown to increase overall yield and chemical characteristics of fruits (Abdelaziz et al. 2019). This positive effect is thought to be related to the enhancement of chlorophyll content and essential nutrient elements such as nitrogen, phosphorus, potassium, (K), manganese (Mn), magnesium, boron (B), zinc (Zn), and iron (Fe) in the leaves. According to Zagzog et al. (2017), spraying mango trees with nano-zinc increases fruit weight, fruit number as well as yield, leaf chlorophyll and carotene levels, and concentrations of numerous nutrient components including N, P, K, and Zn. Similar to this, applying fertilizers containing nano-boron and nano-zinc enhances fruit quality, yields more fruits, and raises total sugar and total phenol content in pomegranates as well as the ratio of total soluble sugars (TSS) to maturity index (Davarpana, 2016).

Nano fertilizer

The process of creating nano fertilizers involves combining plant nutrients with nanomaterials, coating nutrient molecules with a thin layer of nanomaterials, and creating emulsions that are only a few nanometers in size. When compared to conventional fertilizers, nano fertilizers and nano biofertilizers, which contain both natural and synthetic components, wisely boost soil fertility and bioavailability. However, the three most crucial properties of nano fertilizers are (i) a bulk size of about 100 nm; (ii) a particle size of less than 100 nm; and (iii) the nanoproduct must be durable and safe for the environment. Retaining its nanosize and aggregates when interacting with soil particles or agricultural plant roots is another characteristic of a nano fertilizer.

Enhancement of Shelf-Life of Horticultural Crops by Nanomaterials

There are a number of conventional preservation methods; however, they are all costly, ineffective at extending shelf life, or constrained by an unfavourable residue. The employment of shelf-life expansion strategies based on nanotechnology has the potential to minimise the limitations of traditional methods due to a number of regulatory properties of nanomaterials.

Nanofilms/Coatings

Metal nanoparticles (NPs) are transported by nanofilms, which act as protective barriers and antimicrobials. These cutting-edge materials reduce the rate of respiration, control colour change and breakdown, balance storage conditions, and extend the shelf life of horticulture crops. It is suggested that using edible nanofilms is a practical technique to maintain the qualities of horticulture goods during storage and shelf-life. Recently, Dubey et al. (2019) produced a nano-composite edible film made of glycerol, aloevera gel, and ZnO-NPs solutions.

Nano packaging

Nowadays, it is recognized that nano-based technologies are the most efficient in food processing and packaging. Foods with high quality and long shelf lives can be enhanced and preserved with the use of nanoparticles in nano wrapping and processing techniques. Metal nanoparticles as Ag, Cu, TiO_2, and MgO (Islam et al., 2018), edible antibacterial nano-composite films, and gas scavengers (Lee et al., 2015) are examples of active food nano-packaging materials. For instance, by absorbing ethylene gas, the addition of Ag-NPs nanoparticles extended the shelf life of fruits and vegetables (Hu and Fu, 2015). It was discovered that when food is packaged and processed, nanocrystalline TiO_2 acts as an oxygen scavenger (Kuswandi, 2107). Food material shelf life can be increased by Ag-NPs coated packaging materials by reducing microbial activity (Sidorowicz et al., 2021).

Nano sensors in Precision Horticulture

According to Scoville (2018), a nano sensor is any instrument that has the ability to transmit information and proof about the actions and traits of NPs at the nanoscale level to the macro level. Real-time monitoring of fields crop, crop development, and disease and pest incidence requires nano sensors. Metal nanotubes, nanowires, nanofibers, nanocomposites, nanorods, nanostructured polymers, and various allotropes of carbon, such as carbon nanotubes, graphene, and fullerenes, are nanosized materials that can be utilised for sensor fabrication (Márquez and Morant, 2015). With real-time monitoring, agricultural production can use less pesticides and fertilizers than necessary, lowering both production costs and environmental degradation.

Conclusion

Modern agriculture is using nanotechnology as a cutting-edge tool to support sustainable agricultural production. It also holds enormous potential for horticulture, as various nanomaterials are employed to boost production, improve the quality of products, and lower fruit and vegetable rotting after harvest. The power of nanoparticles and their techniques of dispersion are leveraged by nanotechnology to increase crop productivity in the horticultural sector.

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Table1. Influence of nanoparticles (NPs) on germination, growth, development and yield

Nanoparticles	Dose (mg/L)	Crop	Effect on Plant Growth and Development	Reference
TiO2	1000 to 2000	Spinach	Promotes growth and photosynthesis.	Hong et al. 2005
Carbon nanotubes (MWCNT)	10–40	Tomato	Enhances germination and growth rate but inhibits elongation of root in tomato.	Khodakovskaya et al. 2013
Fe3O4	0.67	Lettuce, spinach, radish, cucumber, tomato, peppers	Inhibits seed germination	Torre-Roche et al. 2013
ZnO	100-1000	Garden pea	No effect on seed germination but affects nodulation and root length	Raliya et al. 2015
Carbon nanotubes (MWCNT)	10–40	Onion and cucumber	Enhances elongation of root	Canas et al. 2008

Table 2. Effects of nano components on different horticultural crops

Nanofilm/Coating Component	Beneficial Effect on Fruit	Fruits	References
Chitosan	delays the aging process, water loss, and fruit firmness	Mango	Silva et al., 2017
Chitosan	Improves stiffness, slows down the pace of weight loss, and increases the antioxidant process.	Guava	Silva et al., 2018
Chitosan-carboxymethyl cellulose/Mentha spicata essential oi	The antibacterial properties of the coating work well. Favourably affects respiration rate, pH, water vapour resistance, weight loss, and titratable acidity.	Strawberries	Shahbazi, 2018
Nano-ZnO	Six extra days can be added to the shelf life of fresh-cut apples with nano-packaging.	Apple	Li et al., 2011

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