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Nano-Technology: A Novel Technique In Modern Fruit Production

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ABSTRACT

Nano technology is an emerging potential technique to enhance the fruit productivity with limited inputs in modern fruit production. Nowadays, providing sufficient healthy fruitsis the biggest challenge for the rapidly increasing global population. Generally, 1 to 100 nanometerof tiny sized materials used in this technology. Nowadays, a lot of technology has been developed and adopted in various stages of fruit production.These nano particles are used for producing nano-fertilizers, nano-pesticides,nano-coatings, post harvest dipping, packaging, increasing water use efficiency and plant protection measures. Some of the nano technological based plant extracts (Hexanal) arewidely used to enhance the storage life of mango, banana and papaya fruits.Some other nano materials like Electrospun Nano-Fibre Matrix enhance the post harvest life of mango fruits.Nano technology basedbiosensors (packaging)enhanced the qualityand packaging beautyof most of the fruit crops. Still public awareness is needed for acceptance of nanomaterial based fruit products. In this review,we focused on the application of nanotechnology for enhancing the growth, production, protection and post harvest management of various fruits.

Key words: Nanotechnology, Fruit crops, Nano particles

Introduction:

Climate change, increasing population growth rate and limited natural resources (water and soil) are the global challenges in this era. The climate change impacts on global fruit production are unparalleled, so, in this modern era adoption of nanotechnological tools boost fruit production and sustainability. The nanotechnology concept was first given by Richard P Faynman during his first address mentioned- ‘Plenty of rooms at the bottom’ and suggested the possibility of manipulating materials at nanoscales (Feynman, 1960).The term

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'Nano' is originated from the Greek word and it means 'Dwarf'. It indicates that the use of one billionth sized tiny particles (ranged from 1 to 100 nanometer) in scales expressed as Nano-scale or Nanometer-scale.

A wide range of nano-based precise and microscopic instruments *viz.*, nano-based devices, machines and robots at the atomic level. The adoptions of nano-based technologies minimize input losses and enhance the production by site-targeted specific delivery of applied inputs. The most commonly used nanomaterials used in fruit productions are fruit packaging, nano pesticides, nano fertilizers, nano fungicides, precision fruit culture, and crop improvement. These nanomaterials adopted biosensors are also used in high tech fruit production. In this review, we discussed the advanced and innovative applications of nanotechnologies that might help to enhance fruit production and ecological sustainability. Scientists, manufacturers, and researchers and authorities are neglected the study of public acceptance of nano-based products (Arnaldi and Muratorio, 2013).

In a fruit production industry, it's an urgent need to focus advanced generation tools to accelerate nutrient and water use efficiency, site-targeted delivery of nutrients and pesticides, decaying and postharvest losses. Nowadays this "Nanotechnology" becomes a novel revolutionary tool so; some authors reported this as a sixth revolutionary technology(Mustafa andZaied, 2019).It's a novel tool to bridge the gap between fruit production and increasing fruit consumer demand at the global level. In this review, discussed various applied applications in various aspects of advanced fruit production in this modern era.

Current status of nanotechnology on fruit production

Nanotechnology dealt with the use of nanomaterial of dimensions ranging from 1 to 100nm. Fruit industry reported nanomaterials to include organic (natural NPs), inorganic (includes metals and metal-oxides NPs) and combined (clay). Among the various NPs, metal, and silver NPs are most widely used in fruit production and post-harvest management. Gold and Ti dioxide NPs are used as a sensor or detector and disinfecting agent respectively (He *et al.*, 2019).Nanoparticles are synthesized by physical (Nano-zeolite and nano-clay), chemical (vapor sedimentation, sol-gel, hydrothermal route, microemulsions) and biological methods (Nano-Silver) are reviewed by Mustafa and Zaied, (2019).

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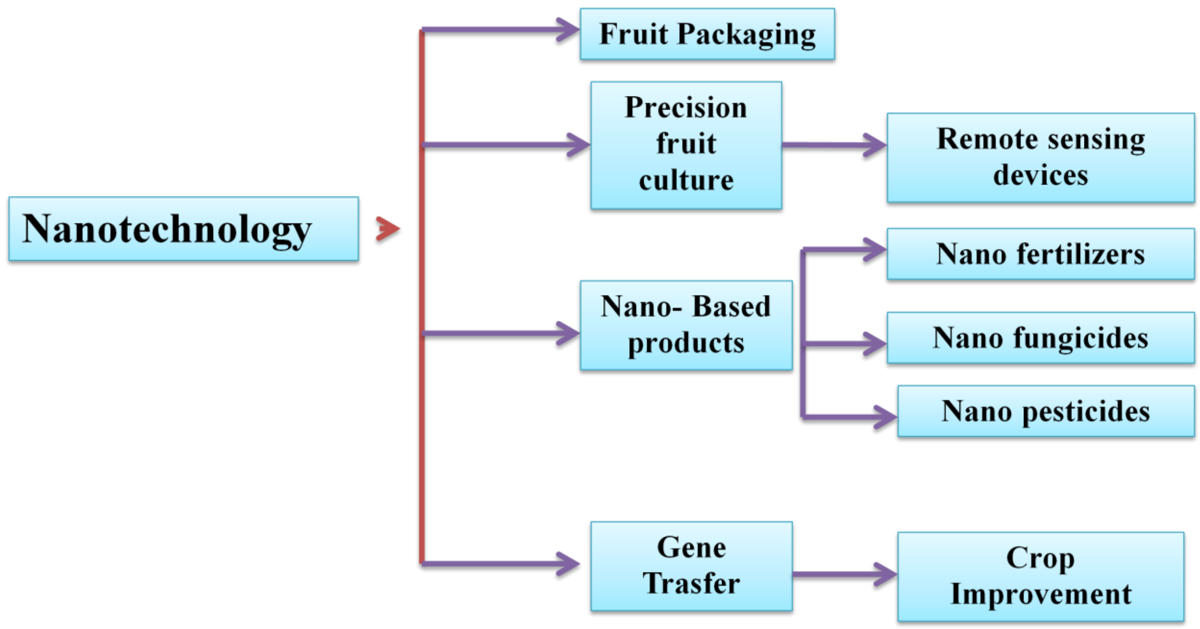
In developed and developing countries the production of fruits or fruit-based marketable products is the most important tool which influence countries economy and needs of daily dietary requirement. Horticulture is an emerging technology, and cultivable area expanding at a rapid rate in developing countries. Increasing the fruit productivity by cultivating advanced and improved cultivars, adopting proper cultural practices (training and pruning), advanced planting systems (HDP, UHDP), fertilizers and irrigation systems, use of chemicals, etc. are a boost to modern fruit production. But the excessive application of chemicals and fertilizers are harmful to the ecosystem and human health (Sharma and Singhvi, 2017).

Fruit production has been improved by the increasing input use efficiency and minimizing the input losses. These nanomaterials have a site-targeting controlled delivery of fertilizers, pesticides, herbicides with increased crop protection. This précised application helps to maximize the quality fruit production with fewer inputs, nano biosensors or nanotools are used in high-tech fruit production (Shang, *et al.* 2019).The commercial applications (**Figure 1.**)of nanotechnologies are discussed in this review.

Figure 1. Schematic representation of applications of nanotechnology in various aspects of fruit culture



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Fruit packaging and post-harvest management: Most of the fruits are highly perishable in nature and have very limited storage life. Bananas, mangoes, and papayas are tender tropical fruits that are in high demand in export markets and an important livelihood source for producers. But freshness is key because these fruits spoil quickly and damage easily. Estimates suggest that up to 40% of produce in tropical countries is lost in post-harvest handling. Breakthrough research by Canadian, Indian and Sri Lankan partner's points to a promising innovation: nanotech applications of a natural plant extract called hexanal can be used to delay fruit ripening. Hexanal inhibits a plant enzyme that is responsible for breaking cell membranes during a fruit's ripening process. The scientists of India and Sri Lanka are also developing "smart packaging" systems, made from materials such as banana fiber, that slowly release hexanal to extend storage life after the fruit is harvested. Postharvest attacks of pathogens (fungi, bacteria, and others) caused spoilage and decaying of fruits. Some stable nano particles (AgNPs) are extracted from fruit peel of black grape (*Vitis vinifera*) and evaluated against various pathogens (against *Bacillus cereus, Staphylococcus aureus, Escherichia coli*, and *Pseudomonas aeruginosa*) and the AgNPs and AgPVA nanofiber reported with good antibacterial activity and surface coating in strawberry and lemon found preventing decay, influenced shelf life of fruits(Kowsalya,*et al.*, 2019).Silver nanoparticles are synthesized from different citrus peel extracts and found that antibacterial activity against *Pseudomonas aeruginosa, Escherichia coli* and *Salmonella typhimurium*(Reenaa and Aathira, 2017). Kumar *et al.* (2019) reported that the enhancement of the postharvest shelf life of green grapes by using promising packaging material *viz.*, fabricated agar-ZnO nanocomposite film. In Mazafati date (*Phoenix dactylifera* L.) reported that the polyethylene (nanocomposite) packaging containing 2% zinc oxide had found better quality and shelf life of fruits at 4 ^{0}C temperature (Sadeghipour, *et al.* 2019).

Silver nanoparticles (AgNps) are widely used for postharvest treatments of fruits because of its antimicrobial and antibacterial properties. Silver nanoparticles (AgNps) synthesized by green synthesis with Citrus limon peel extract are found better quality and shelflife of blackberry (Rodino, *et al.* 2019).In Mango, polylactic acid nanocomposite filmscontaining bergamot essential oil, TiO_2 nanoparticles, and Ag nanoparticles reduce the weight loss, fruit firmness andenhance the shelf life of 15 days (Chi, *et al.*

2019).Nanocomposite edible coated films containing glycerol and ZnO nanoparticles improve the fruit quality and storability of mango fruits (Dubey, *et al.* 2019).Guava fruit packaging alginate and chitosan-based edible fruit coatings are found suitable and incorporation of nano ZnO to both chitosan and alginate was found an efficient action against antimicrobials and also extend the fruit shelf life of twenty days (Arroyo, *et al.* 2019). These types of packaging also reduce environmental impact. Because of attractive physicochemical properties, the nano-ZnO gained its importance on a commercial scale. Increase in the shelf life of fresh-cut 'Fuji' apple was found by nano packaging with polyvinyl chloride (PVC) film with nano-ZnO powder at 4°C for 12days (Li, *et al.* 2011).Some nanomaterial-based stickers are developed viz., Electrospun Nano-Fibre Matrix (sticker) enhance the post-harvest storage life by controlling hexanal production of mango fruits (Shanmugapriya, *et al.* 2016). Nano based chitosan/nano-silica (semi-permeable film) inhibit the malondialdehyde amount increase and the activity of polyphenol oxidase enzyme, reduce the fruit weight loss, browning and enhance the storage life of longan fruits (Shi, *et al.* 2013)

Precision fruit culture:

Nowadays precision fruit culture is an urgent need for measuring and monitoring tree growth, soil conditions (moisture, nutrients, pH, EC, etc.), detection of diseases, agrochemicals penetration and environmental effect. By precision fruit culture, we can enhance the assured fruit quality, maintain soil and plant health in sustainable fruit production and environmental safety (Chen, *et al.* 2016). Nanomaterial engineering adopted in high-tech fruit culture by offering a wider specific surface area for the sustainable development system (Panpatte*et al.*, 2016 and He, *et al.* 2018). Therefore, the use of nanotechnology applications is an advanced technique in modern fruit culture. The important application in nano-fruit culture is for high-quality fruit production by using low input use costs and also maintains the ecological sustainability. In this culture, nanosensors, nano technological-based global positioning systems, supercomputers, and remote sensing devices are used in this modern era.

a) Nano based biosensors:Nanomaterial-based biosensors are widely used for the early detection of diagnosing different kinds of pathogens (fungal, bacterial and viral) and food toxins (Chartuprayoon*et al.* 2010; Bansi, *et al.*, 2014 and Wang, *et al*. 2019). Recently nano-based biosensors are used for fast detection of the presence of pathogens in plant tissues by using DNA, antibody and biosensing receptors (Volatile compounds). these techniques are economical, non-destructive and early detection of the pathogen, minimally invasive, specificity, sensitivity, and on-field plant pathogen detections (Kashyap, *et al.* 2019). the detailed aspects of nano-based biosensors used in the agricultural sector (Kashyap, *et al.* 2019) are i) Fluorescence Resonance Energy Transfer (FRET) Nanosensor, ii) Surface-Enhanced Raman Scattering (SERS) Nanosensor, iii) Electrochemical Nanosensors (ECN), iv) Piezoelectric Nanosensor (PZN).

Citrus greening also was known as yellow shoot disease and huanglongbing (HLB) is a lethal disease in citriculture. Volatile organic compounds are easily distinguished by using an electrical sensor array for early-stage on-farm detection of citrus greening bacterial diseases (Wang, *et al.* 2019). Ceria nanoparticles are microsensor based on the quantification of limonin used to detect yellow shoot disease (huanglongbing) by using an Organic Electrochemical transistor platform (Saraf, *et al.*, 2018). Fernández-Baldo*et al.* (2010) by using fabricated a carbon-based screen-printed electrode using microfluidics principles quantify the *Botrytis cinerea* infection level in apple, pear, and grapefruits. Plum Pox Virus (PPV) also known as sharka, is most common in plums and other stone fruits. it causes economic loss by infecting fruits so, frequent monitoring and early detection of the pathogen are necessary for effective management of the disease. Based on electrolyte-gated organic field-effect transistor (EGOFET), Bioelectronic PPV biosensors are developed for early detection of specific virus (PPV) in the plant extract (Berto, et al. 2018). Nano based optical biosensors are developed for determination of Grapevine virus A-type (GVA) proteins (GVA-antigens) without any additional labels with the sensitivity range from 1 pg/ml to10 ng/ml (Tereshchenko, *et al.*, 2017), Quantum dot-based biosensors are also used for detection of virus diseases (Hong and Lee, 2018). In Australia, sensor based LiDAR components are developed with automatic image masks generation for single, double and multi-view approach to detecting, counting, tracking and specific fruit location of fruit within trees for precise fruit yield estimation without statistical calibration (Stein, *et al.* 2016).

Nano-Based products:

a) Nanofertlizers: Wide range use of chemical fertilizers in fruit production cause serious cause of soil fertility status, microorganism activity, mineral cycles, etc. improper and unscientific excess use of fertilizers alter soil acidity, decrease in nutrient use efficiency, pH, nutrient toxicity, nutrient immobility cause several nutrient deficiencies in fruit crops.

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However, nano fertilizer application reduces nutrient leaching, emissions, and long-term reaction with soil microorganisms without affecting environmental contamination. Nano fertilizers (NFs) are the most widely investigated and developed in fruit culture. They play an important role in vegetative and reproductive growth, flowering so it will help for accelerating fruit productivity, quality and postharvest life of fruits. Generally, like growth regulators sprayed at lower concentrations different intervals of time with frequent sessions act as a growth stimulant. Nanocomposites fertilizers *viz.*,ZnFeMnB (zinc, iron, manganese, boron), NPKMg (nitrogen, phosphorus, potassium, magnesium) and Macro- and micro-scale nano fertilizers *viz.*, zinc, boron, chitosan, and calcite has been developed and shown significantly improvement in the vegetative and reproductive traits of fruit trees *viz.*, coffee, date palm, strawberry, pomegranate, mango, and grape (Zahedi, *et al.* 2019).

A single dose of foliar application of nano fertilizers (B or Zn) at lower concentration (34 mg B tree^{-1} or 636 mg Zn tree^{-1}, respectively) enhance the pomegranate (Cultivar Ardestani) yield and fruit quality parameter (Davarpanah, *et al.*2016). Spraying of nano-zinc at 0.4 ppm was improved the vegetative parameters in grapevine (Rasha El-Said, *et al.* 2019). Malandrakis, *et al.* (2019b) reported that the apple fruits spray with ZnO, CuO and Ag NPs with the concentration of 100 and 1000 µg/mL for four days suppresses the growth of graymold (*B. cinerea*) and soil-borne diseases. Preharvest application of nano calcium was improved the post-harvest fruit quality and enzyme activity of the cell wall of apple fruit cv. Red Delicious (Ranjbar, *et al.* 2019). Enhancement of overall fruit quality by the application of nano-fertilizers and NPK was observed in date palm (Jubeir and Ahmed, 2019).

b) Nano fungicides:

Nanoparticulate based bio-fungicides or fungicides play a unique role in controlling targeted diseases of fungal origin in fruit culture. Plant protection is an essential tool to maximize the fruit production, application of herbicides, insecticides and fungicides at large scale affects the soil fertility and environmental sustainability (Nuruzzaman, *et al.* 2016). So, target specific pest and disease control is essential in modern fruit culture, apart from this it also assures better protection from pathogens. Nanoformulations or encapsulation of fungicides contain nano-sized particles in the pesticides and other pesticidal properties are engineered nano-structures (Haq, *et al.* 2019). Coating of pesticides with active ingredients called

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nanoencapsulation means core material is insecticide or pesticide (internal phase) and the external phase is coated with nanomaterial (Nuruzzaman, *et al.* 2016).

Nano based derivatives of *Chaetomium cupreumviz.,* nano-CCM, nano-CCE and Nano-CCH are inhibiting the growth of *Phytophthora spp.* growth of mycelium and spore production of root rot of durian (*Duriozibethinus*Murr.) (Thongkham, *et al.* 2017). *Citrus trifoliata* essential oil (CTEO) loaded nano-cubosomes (self-assembled cubic liquid crystalline nanoparticles) was effective against fungal diseases *viz.,Fusarium oxysporum* and *Fusarium solani* (Abdel-Kawy, *et al.,* 2019). ZnO NPs in the in-vitro condition under visible light reported strong antifungal activity, spraying of ZnO NPs during sunny days reduces the incidence of *Botrytis* and accelerate fruit quality and decay loss of strawberry fruits (Luksiene, *et al.* 2019), Cu-NPs is also found effective against *Botrytis spp.* (Malandrakis, *et al.* 2019a).

c) Nano pesticides: These are also similar to the form of nano fungicides, formed by encapsulation of pesticides. The conventional use of pesticides increases the resistance of targeted pests and also injure the other beneficial organisms. These nano pesticides help to overcome these controversial limitations (Dwivedi, *et al.* 2016). *Citrus trifoliata* essential oil (CTEO) loaded nano-cubosomes (self-assembled cubic liquid crystalline nanoparticles) was effective against insects *viz.,Spodopteralittoralis* (Abdel-Kawy, *et al.*, 2019). Nanomaterial based kaolin particle films is act as a physical barrier for controlling insect pests the Mediterranean fruit fly *Ceratitiscapitata* (Diptera: Tephritidae) and Southern green stink bug *Nezaraviridula* (Heteroptera: Pentatomidae) (Salerno, *et al.* 2019). Nano gel-based low-molecular-mass gelators of methyl eugenol (ME) are developed for effective control of *Bactrocera dorsalis* of many commercial fruit crops (Bhagat, *et al.* 2013).

Crop improvement: Practical applications of nanotechnology in crop improvements achieved through biotechnology. Nanomaterials are move through the phloem tissues and accumulate in plant storage organs (sink) *viz.,* fruits, grains, tubers, etc. However, translocations of these materials are not restricted for specific cell types, and lateral movement is also possible between xylem and phloem tissues (Pate, 1975, Pérez-de-Luque, 2017). It mainly used to deliver DNA and chemicals to plant cells with precise control. Other applications of nanomaterials are controlled and multiple gene delivery; and to study the gene function in a cell. Chitosan nanoparticles entrapped SiRNA delivery vehicles are developed and found an effective binding potential with RNA and the ability of penetration through the cell membranes (Zhang, *et al.* 2010). Nowadays nanoparticles are gaining importance in genetic engineering such as genome editing in plants (Miller, *et al.* 2017 and Mout*et al* .2017).

Conclusion: In the field of horticulture, nanotechnology has to gain importance in quality fruit production. The nanotechnological based particle plays a role in fruit packaging and post-harvest management, nano fertilizers, nano pesticides, nano herbicides, genetic engineering, and genome editing, etc. The use of these particles protects the ecosystem from pollution and project towards sustainable production. Nanomaterials have a potential role in increasing the fruit yield by reducing farm risks. The nanomaterials used for targeted site-specific management of pest and diseases, targeted and slow delivery (smart delivery) of nutrients, pest and disease detection by using biosensors and gene delivery in fruit crops. The nanoparticles applications use will revolutionize the fruit production and it will increase the productivity with the reduction of input use. Hence it's a highly potential role in precise and sustainable fruit production in developing countries. Still, it's an urgent need to adopt or incorporate nanotechnology in fruit production systems on various fruit crops (tropical, subtropical and temperate crops) and its applications under field conditions.

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