THE USE OF NANOTECHNOLOGY IN HORTICULTURE TO PROMOTE SUSTAINABILITY

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The most important elements for human survival and social sustainability are ecological balance, a healthy environment, the reduction of climate change, access to food and nutrition, and good health. According to projections, there will be over 9 billion people on the planet by 2050, which means developing nations like India will face exponentially greater demand for food, water, and energy. The horticultural industry is facing more and more challenges with sustainability and awareness. By preserving an economically viable production system and halting environmental degradation, the effects of difficulties can be reduced. With the development of new instruments that can improve the production of planting material, give new and effective fertilizers, extend the shelf life of produce, and other areas, horticulture has the potential to advance.etc. In a sustainable manner. Nanofertilizer, one of the most significant uses of nanotechnology, enhances plants' capacity to absorb nutrients and Zn, Cu, and Fe nanofertilizers improve soil fixation and increase photosynthetic efficiency. Other names for nanofertilizers include nano-carriers, nano-enabled fertilizers, bio-nanofertilizers, controlled-release nanofertilizers, nanoparticles-based nutrients, and nano-based delivery systems of micronutrients. These fertilizers give nutrients at the proper time and location As a result, it's critical to boost yield and production rates of high-quality products, boost input efficiency, and cut waste without harming the environment in order to fulfil future demand. Basic and in-depth knowledge of nanomaterials is necessary before nanotechnology applications integrated in an eco-friendly way can be used in horticulture.

Nanotechnology

Nanotechnology is a new scientific approach that includes the use of materials and equipment capable of using physical and chemical properties of a substance at molecular levels to explore the biological and material worlds in nanometer-scale and use it in various carriers from medicine to agriculture. Nanotechnology is the study and technology of tiny things, the materials that are less than 100 nm in size. One nanometer is 10^{-9} metres; Nanotechnology includes solid state physics, chemistry, chemical engineering, biochemistry, biophysics, and materials science. Grouping of Nanoparticles

Classification of Nano-particles

In general, nanoparticles can be classified on the basis of their:

• **Dimension**: One dimension (nano plates, nano films, etc.), two dimensions (nano fibres, nanowires, nanorods, nanotubes, etc.), three dimensions (nanoparticles, quantum dots, nanoshells, nanorings, microcapsules, etc.).

• **Morphology:** Shape (spherical, triangular, hexagonal, rod shaped, etc.); Size (10 nm, 20 nm, 35 nm, etc.),

• **Composition**: Carbon and non-metallic nanoparticle, metal nanoparticle, semiconductor nanoparticle, etc.,

• **Uniformity:** Uniform in shape, size, composition, etc.,

• **Agglomeration**: It is the property of nanoparticles by which nuclei of small particles fuse together to form a large nanoparticle when they are present in high concentration. It varies depending on the type and concentration of nanoparticles i.e., different metals have different agglomeration rate.

But broadly nanoparticles can be classified into two categories:

• **Organic nanoparticles**: These include carbon nanoparticles (dendrimers, liposomes, ferritin, micelles, etc.)

• **Inorganic nanoparticles**: These include nanoparticles of metals such as Ag, Au, Pd and Pt, nanoparticles with magnetic properties such as Fe_2O_3, Fe_3O_4, lanthanide oxide, etc. and nanoparticles like SiO_2, TiO_2, ZnO, quantum dots, etc. having semiconductor properties.

Methods of Nano-particle Production

According to the Royal Society and Royal Academy of Engineering, there are two main ways to create nanomaterials: Topdown, which involves size reduction of bulk materials and Bottom-up, which involves synthesis of materials at the atomic level.

Top-down systems: These systems use mechanical-physical techniques like grinding, milling, and crushing to produce nanoparticles, which are then used to produce nanocomposites and nano-grained bulk materials with a wide size distribution, like metallic and ceramic nanomaterials, by tiny manipulations of a small number of atoms or molecules (10 - 1000 nm)

Bottom-up system: During "Bottom-up" building up, several molecules self-assemble in parallel phases in accordance with their molecular recognition characteristics. This processing results in increasingly complicated structures from atoms or molecules, and it also results in uniformly controlled sizes. Nanomaterials come in various forms and sizes. This technique is typically employed to prepare the majority of nanoscale (1–100 nm) materialsit is plays an essential role in the production of nanostructures and nanomaterial. Additionally, there are alternative ways to create nanomaterials, including pyrolysis, attrition, and biological nanoparticle synthesis.

Nanoparticles for Sustainable Horticulture

The explosive rise in the world population demands higher productivity of agricultural commodities to feed the growing population. Nanotechnology has the potential in improving food production, food quality, plant protection, detection of diseases, monitoring of plant growth by remote sensing and reduce waste for "sustainable amplification" (Prasad et al., 2014). Nanoparticles are playing a remarkable role in horticulture by their application in nano fertilizers, sensors for monitoring quality of soil, nano pesticides for disease and pest management, improved packaging for enhancing shelf-life and also in production of quality planting material.

Nano products for horticultural crops

Nanomaterials have attracted increasing attention because of their potential impact on a wide range of industries and markets. TiO_2 has been the focus of photo catalysts under UV irradiation because of its physical and chemicalst ability, low-cost, ease of availability and non toxicity

Seed Germination

Plant propagation is the process of the multiplication of plants by both sexual and asexual means. Sexual reproduction method produces offspring by the fusion of gametes, resulting in a genetically different plant from the parents due to genetic exchange that occurs during fertilization between male and female parent. Seeds are typically produced from sexual reproduction in plants. Asexual reproduction produces new individuals without the fusion of gametes and therefore the offspring are genetically identical within themselves and to the parent plant and especially the cross-pollinated ones are mostly reproduced by asexual methods of plant propagation to produce identical clones but certain fruits and most of the vegetables and ornamentals can only be multiplied through seeds. Farmers face many problems while propagating plants through seeds, as seeds of many crops exhibit different types of germination hindrances like dormancy. Dormancy may be physical, physiological, morphological or combination of more than one depending on external or internal factors. These seeds require special conditions and treatments to improve germination percentage and break their dormancy. The treatments such as stratification, scarification, high temperature, growth regulators, etc. are normally applied to enhance the germination rate. Even after breaking dormancy, sometimes plants show very less germination percentage. The chemical compounds present in seed kernels, structure of seed-coat, presence of inhibitors like abscisic acid or phenolic content in testa and the capacity of the embryo to form gibberellins, promote dormancy and adversely affect the percent germination (Hartmann et al., 1997).). To overcome these problems, among the different methods applied, soaking seeds in Nano Particless solution can definitely prove as a great option for enhancing seed germination. Treating seeds at 1% concentrations of TiO_2-Nano Particles for 20 min resulted in the highest germination percentage (65%). The highest total seedling height was obtained after exposure of seeds to 0.5% TiO2-Nano Particles for 10 min. Irrigation of seedlings with TiO2-Nano Particles at the concentration of 1% seems to be a suitable method how to increase their total height, survival, and total dry weight. A decrease in the relative water content and an increase in proline were observed in response to the application of high levels of Nano Particles. Pd and Au nanoparticles at low concentrations (P values of 0.002 and 0.008), Si and Cu nanoparticles at higher concentration (P values of 0.0016 and 0.003) and a combination of Au and Cu nanoparticles (P value of 0.006) significantly influences the plant growth after 15 days of incubation. There is an increase in the shoot/ root ratio for the above mentioned nanoparticles compared to that of the control indicating that these nanoparticles do affect the growth of the plants. The experiment included five levels nanosilicon oxide (0, 25, 50, 100, and 200 mg/L) added to Murashige and Skoog medium. The results showed that using nanosilicon increased in fresh and dry weights, length and number of branches, and chlorophyll in explants with the highest increase being at 100 mg/L.Growth suppression occurred at 200 mg/L. This investigation showed that 100 mg/L silicon oxide can be added to Murashige and Skoog medium for fast growth and proliferation of MM106 apple rootstock explants.

Micropropagation

Micropropagation has proven to be an effective method for large-scale plant production in a short time and a useful tool for plant breeding. The sterilization effects of silver nanoparticles (AgNP) on the growth of explants and culture media were examined. The treatment with 250 ppm AgNP for 15 to 20 min of 4-wk-old ex vitro leaves proved optimal for controlling the contamination.. Tung, H. T. *et* al(2021). Numerous variables, including the donor plant, the age and kind of the explant, the culture medium, growth regulators, etc., affect the success of commercial in vitro propagation. Lower concentrations of silver nanoparticles produced better results for the number of embryos and shoots in date palms than higher concentrations, but higher concentrations of silver nanoparticles produced the maximum callus formation, callus growth, and globularization (El-Kosary, et al 2020). The peptide substrates' tyrosine residues are dephosphorylated by the nanoparticles, which inhibits signal transduction and prevents the development of bacteria (Mittal et al., 2014).

Growth and Development of Plants

Foliar application of nano- zinc and boron fertilizers was found to increase fruit yield and quality, including 4.4–7.6% increases in total soluble solids (TSS), 9.5–29.1% decreases in titratable acidity (TA), 20.6–46.1% increases in maturity index and 0.28–0.62 pH unit increases in juice pH on pomegranate (*Punica granatum*) without affecting any physical fruit characteristics (Davarpanah *et al* 2016). Avestan et al. (2015) investigated the effects of in vitro application of nano SiO_2 on growth and proliferation of apple rootstock MM106 and reported that nano silicon significantly increased fresh and dry weights, length and number of branches, and chlorophyll content in microplants. Thus, they concluded that, silicon oxide can be added to Murashige and Skoog medium for fast growth and proliferation of explants. Zhen *et al*. (2005) demonstrated that the application of TiO_2 at 2.5% level increased photosynthesis in spinach about 3.13%.

Abiotic stress tolerance

In general, elements that directly affect a plant's physiological processes including photosynthesis, respiration rate, metabolism, nutrition and water transport have an impact on a plant's growth and development. Drought, salinity, radiation, wounding, temperature, hypoxia, and metal toxicity are the principal abiotic stressors. These abiotic stressors have a negative impact on crop growth and productivity (Boyer 1982; Adisa et al. 2019; Verma et al. 2019, 2020). The expression of different genes changes these pathways, causing the plant to adapt to abiotic stressors**.**

Drought Stress

Drought conditions are typically brought on by elevated temperatures, little precipitation, dry winds, intense sunlight, and a quick evaporation rate of water from the soil. The plant does not receive enough water as a result of these unfavourable circumstances, which ultimately hinders its growth and development. Different concentrations of nanoparticle application have been observed to increase plant tolerance to similar drought stresses (Das and Das 2019).

Drought conditions cause a variety of defects in plants, including reduced leaf size, stem extension, root proliferation, and disturbed plant water relationships, which reduces the amount of water and nutrients that plants can absorb from the soil. The relative water content, photosynthesis, membrane electrolyte leakage channel, chlorophyll, carotenoid, carbohydrate, and proline (Das and Das 2019). The presence of silicon Nano Particles in Hawthron plant help in maintaining critical physiological and biochemical conditions for avoiding drought affect under drought stress but adaptation mechanism is not well understood (Ashkavand et al. 2015). The application of Nano Particles into a plant growth medium performed various defense mechanism to protect the plant as

A) It reduces the penetrability of plasma wall of leaf cells resulting in the loss of lipid peroxidation.

B) It also protects the plant cell wall against drought and heat stress (Zhu et al. 2004). In comparison to common silica fertilizer, the use of silica Nano Particles enhances amount of proline in plants (Kalteh et al. 2014).

Moreover, it helps to increase activities of peroxidase and catalase in stressed plant leaves and also increase water efficiency during stress condition. Similarly, application of TiO_2Nano Particles led to an increase in the rate of germination, chlorophyll formation, RuBisco, photosynthesis during drought stress (Hong et al. 2005; Zheng et al. 2005).

Salinity Stress

Accumulation of excessive salt contents in the soil directly or indirectly inhibited crop growth and results in decreased crop production More than 20% of cultivated land is reportedly damaged by salt stress, and this percentage is steadily rising. Through the production of reactive oxygen species and increased osmotic stress, salinity stress has a detrimental impact on the growth of plants. Similar to how ion toxicity modifies the biochemical processes, reducing leaf water potential causes physiological and morphological alterations (Rajput *et al.* 2015). When silicon fertiliser and silicon nanoparticles were applied to basil plants (*Ocimum basilicum*) during salt stress perfusion, Kalteh *et al*. (2014) observed improved growth and development as well as higher levels of chlorophyll and proline. (Kalteh *et al.* 2014). Application of SiO2NPs is reported to increase chlorophyll content, leaf dry weight, leaf fresh weight, and proline amount, which synthesized antioxidant enzyme under salt stress (Haghighi et al. 2012). The most prevalent macro-mineral nutrient in soil is silicon, which ions assist in reducing various forms of stress in plants. Application of Si ions and silica NanoParticles to rice demonstrates enhanced osmolyte synthesis and antioxidant defence system activation (Abdel-Haliem *et al.* 2017; Verma *et al.* 2020).

Plant Nutrition

Nanotechnology plays a pivotal role in the various crop improvement programmes to enhance the yield production. Nanoparticles (NPs) have unique physicochemical properties, i.e. high surface area, high reactivity, tunable pore size, and particle morphology. An important body of scientifc research highlights the role of carbon nanomaterials, metal nanoparticles and metal oxide nanoparticles to improve plant development through the modulation of physiological and metabolic processes. Modulating nutrient concentrations, photosynthesis processes and antioxidant enzyme activities have led to increases in shoot length, root development, photosynthetic pigments and fruit yield. NanoParticles show positive effect on growth by regulating the channel proteins which control water permeability, gene activation and cell cycle (Khodakovskaya *et al.*, 2012). Studies done by Prasad *et al.* (2012) suggested that nano zinc oxide (ZnO) enhanced the vigor of the seedlings favoring earlier establishment in soil, high chlorophyll content and early flowering. The Nano Particles due to their small size can be easily absorbed by the roots through apo plastic or symplastic pathways from endodermis till xylem and then they are transported through the vascular bundles to the different parts of the plant consequently resulting in better growth. Similar type of transport is seen in Nano Particles of mesoporous silica, and ZnO, which are transported inside the cells through endocytosis (Morales-Díaz *et al*., 2017)

Plant Protection

Indiscriminate use of synthetic chemical pesticides has led to several environmental problems such as resistance and environment pollution. Agriculture and food systems may undergo a change thanks to nanotechnology, which is seen as a rapidly developing sector. To create nanopesticides with strong fungicidal and miticidal characteristics, we used nanotechnological interventions. Encapsulation technology was used to create nanosulfur and nanohexaconazole. Micronized chemical pesticides have been used extensively to manage crop plant pests and diseases. These compounds' nano formulation has gotten a lot of attention recently. Algae, Alfa alfa, Aloe vera, *Azadirachta*, *Solanum*, and different kinds of bacteria, fungus, and plants (such as *Lactobacillus*, *Thermomonospora*, *Fusarium*, *Phoma*, and *Verticillium*) are used in the biological synthesis of nanoparticles (NPs) of metallic compounds (*Sargassum*, *Chlorella*). Numerous phytopathogens, including *Bipolaris sorokiniana*, *Fusarium culmorum*, *Rafflaea* sp., *Rhizoctonia solani*, *Sclerotinia sclerotiorum*, and *Magnaporthe grisea*, have been reported to be controlled by silver nano particles. Additionally, *Xanthomonas oryzae pv. Oryzae* caused rice bacterial blight disease and *X. campestris pv. phseoli*-caused mung leaf spot could both be controlled by nano copper. White fly (*Trialeuroded vaporarium*), coconut mite (*Dermanyssus gallinae*), and mustard weevil may all be successfully controlled with nano-silica (*Phaedon cochleariae*). For the control of the significant storage insect pest known as the rice weevil (Sitophilus oryzae), our consortium has created a unique nano-silica. Hexaconazole and sulphur in nanoforms have been discovered to be very efficient against the phytopathogens *Rhizoctonia solani* and *Erysiphe cichoracearum*. The red spider mite(*Tetranychus urticae*). was likewise found to be easier to control with nano sulphur. It was more than ten times effective as compared to commercial sulfur. This implies lesser cost for pest management.

Common Nano Pesticides Used in Horticulture

Nano capsules are vesicular structures comprising of a polymer coating or membrane surrounding an inner central cavity confining the AI (either hydrophilic or hydrophobic). Pereira *et al.* (2014) synthesized poly-ε-caprolactone (PCL) nano capsules containing atrazine herbicide and after testing reported that nanoencapsulation did not change the herbicide mode of action and was active only against the target organism. The nano encapsulated herbicide showed an increase in bioavailability and was proved to be more effective against the target organism as compared to the non-encapsulated herbicide. This was mainly due to the surfactants used for encapsulation of atrazine in PCL nano capsules which reduced binding of herbicide to soil colloids thereby contributing to their increased availability and reduced genotoxicity and soil pollution. Amphiphilic block copolymers called micelles come together in water to create colloidal particles that have a hydrophobic micellar core encased in a hydrophilic corona. Water-swelling nanoscale hydrophilic or amphiphilic polymeric chains that are cross-linked with one another and can swell but not dissolve in water are known as nanogels (Kabano & Vinogradov, 2009). In order to reduce the population of the dangerous fruitfly *Bactrocera dorsalis*, Bhagat *et al.* (2013) used a bait trap made of a nanogel formulation of the pheromone methyl eugenol (ME).

Solid lipid nanoparticles (SLNs) are synthesized by dispersing fat particles in an aqueous phase and the dispersion is stabilized by surfactants. They have high melting point with spherical morphology. Lai et al. (2006) developed a new eco-friendly pesticide by incorporating essential oil of *Artemisia arborescens* L. into SLNs. *A. arborescens* L. essential oil exhibits pesticidal activity against *Aphis gossypii* (a pest of Cucurbitaceae, Rutaceae and malvaceae family), *Bemisia tabaci* (sweet potato white y), and *Lymantria dispar* L. (pest of *Quercus suber*). They reported that SLN formulations integrated with *A. arborescens L* essential oil was not only highly stable, but also prevented rapid evaporation of the AI of essential oil and controlled its slow release. Sustainable release of pesticides not only enhance the efficacy but also at the same time reduce the dose required to get the optimum effect. Prado *et al.* (2011) used nanosized silica to develop an improved carrier for all types of herbicide. They first experimented on picloram herbicide and after getting promising results, they predicted the potential use for different other herbicides. Suitable functional groups were introduced that can act as site for binding of pesticides while maintaining the efficiency of weed control. Cinnamic acid is a naturally occurring organic acid with antibacterial and antifungal activities. Park et al. (2010) synthesized an LDH-cinnamate complex and studied its antimicrobial action. R. Rai *et al*. property against *Phytophthora capsici*, a plant pathogen that causes blight and fruit rot in peppers and other commercial crops. They found that 6 days after inoculation with the pathogen, the red peppers in the free cinnamic acid soil got infected with root rot and wilted, while the red peppers in the soils treated with LDH-cinnamate complexes remained unaffected. Thus, they reported that incorporation of cinnamate inside the Mg/Al layered double hydroxide protected the AI against degradation and also rendered slow-release properties within the complexes. Anjali *et al*. (2012) synthesized neem-oil based nano pesticides as O/W nano emulsions. They used Tween 20 as hydrophilic surfactant and obtained nano emulsions with a droplet size of 31.03 nm at an oil: surfactant ratio of 1:3 and reported a decrease in LC50 value with decrease in droplet size. Thus, Nano pesticides prepared from natural ingredients are biodegradable and environmentally friendly and as well as are economical as they come from a renewable source.

Post-harvest Management and Shelf Life

Controlling Growth and Development of Micro Organisms

A Eurobarometer survey conducted towards the end of the last century showed that the most important issue for 68% of consumers was the safety of the fruit they consumed.). Numerous microbial, physical and chemical hazards occur in the human food chain that contribute to this important safety issue. Many pesticides used in fruit production and storage have been banned due to concerns about pesticides and other chemical residues. Physical contaminants (foreign matter) such as glass shards, wood, dirt, plastic, or metal parts such as nuts, bolts, nails, etc. that enter fruit can cause illness and injury to consumers. Gray mold caused by *Botrytis cinerea* is considered an important post-harvest pathogen worldwide. It causes rot in many economically important fruits and vegetables during the growing season and post-harvest storage. It is also a major obstacle to long-distance transport and storage (Sommer *et al.*, 1992). This fungal pathogen invades leaves, stems, flowers, and fruits directly or through wounds caused by cultivation practices. and vegetables, control during storage is particularly important. On the other hand, losses can be mitigated by fungicide treatments that can ensure product protection, but these are only approved for some food crop species. Public awareness of its negative impact on human health and the environment has led to the deregulation of major chemical fungicides. Another important point is the emergence of pathogens resistant to synthetic fungicides. Therefore, the fresh produce industry is placing increasing emphasis on environmentally friendly technologies, and the search for safer alternatives to chemical fungicides has received much attention (Arul, 1994; *Meng et al.*, 2008). Nanotechnology is using for antifungal in many fruits and vegetables. A technology has been developed to produce zincoxide nanoparticles using microbial approach. Some nanoparticles have been used for antifungal in vitro culture and postharvest of banana, carrot, tomato, onion and etc.

Introducing a New Generation of Packaging Coverage's (Films) and the Polishes Ability to Control Influence of Gases and Harmful Rays

Appropriate selection of ingredients and packaging techniques can maintain product quality and freshness for the required period of marketing and consumption (Stewart *et al*., 2002). Polymer composites are mixtures of polymers and inorganic or organic additives with specific shapes (fibers, flakes, spheres, particles). The use of nanoscale fillers has led to the development of polymer nanocomposites and represents a radical alternative to these traditional polymer composites (Sinha Ray and Okamoto, 2003). Application of nanocomposites promises to expand the use of edible and biodegradable films (Sinha Ray and Bousmina, 2005). Unfortunately, the use of biodegradable films for food packaging is severely limited by the poor barrier properties and weak mechanical properties exhibited by natural polymers. For this reason, natural polymers are often blended with other synthetic polymers and, in rare cases, chemically modified to extend their application to more specialized or challenging conditions (Petersen *et al*., 1999). . Helps reduce packaging waste associated with processed foods and preserves fresh food for longer shelf life. Nanocomposites also have additional advantages such as low density, transparency, good flowability, excellent surface properties and recyclability. In recent years, nanomaterials have received increasing attention due to their potential impact on various industries and markets (Chen and Hu, 2005). General requirements for polymers in fruit and food packaging are summarized in Figure 1. TiO_2 has become the focus of photocatalysis under UV irradiation due to its physical and chemical stability, low cost, ready availability, and non-toxicity. NanoTiO_2 with photocatalytic properties can oxidize ethylene to water and CO_2 (Hu and Fu, 2003). Photoactivity, photocatalysis, and antibacterial action of silver ions. Nano-silver with small size, quantum and large external area effect can have more effective antibacterial activity than Ag+. Furthermore, nano-Ag absorbs and degrades ethylene 52 (Hu and Fu, 2003). In recent years, nanomaterials have received increasing attention due to their potential impact on various industries and markets. TiO_2 has become the focus of photocatalysis under UV irradiation due to its physical and chemical stability, low cost, ready availability, and non-toxicity. Nano TiO_2 with photocatalytic properties can oxidize ethylene to water and CO_2. Silver ions have also attracted the interest of several researchers because of their photoactivity, semiconductor photocatalysis, nanocrystallites, and antibacterial activity. small dimensional nanosilver.

Nano-silver with small size, quantum and large external area effect can have more effective antibacterial activity than Ag+. Furthermore, nano-Ag absorbs and degrades ethylene 52 (Hu and Fu, 2003). In recent years, nanomaterials have received increasing attention due to their potential impact on various industries and markets. TiO_2 has become the focus of photocatalysis under UV irradiation due to its physical and chemical stability, low cost, ready availability, and non-toxicity. Nano TiO_2 with photocatalytic properties can oxidize ethylene to water and CO_2. Silver ions have also attracted the interest of several researchers because of their photoactivity, semiconductor photocatalysis, nanocrystallites, and antibacterial activity. Nano-silver with small size, quantum and large external area effect can have more effective antibacterial activity than Ag+. Nano-Ag also has the ability to absorb and decompose ethylene (Hu and Fu, 2003).

Improving Strength, Quality and Packaging Beauty

A major effort to improve food quality while extending shelf life and reducing packaging waste is driving research into new bio-based packaging materials, such as edible and biodegradable films made from renewable resources. promoted (Tharanathan, 2003). The use of these materials has the potential to at least partially solve the waste problem due to their biodegradable nature. Nanotechnology is widely used in the food industry. According to a study by Li and Wang (2006), Fuji apples containing nano-SiOx/chitosan preservatives were of high quality.

Nanopackaged green tea retained better vitamin C, chlorophyll, polyphenols, and amino acids than regular package (Hu and Fu, 2003). The aim of this study was to prepare a novel nanopackaging material and investigate its effect on the preservation of jujubes during room temperature storage. The nanocomposite concept represents an exciting way to create new and innovative materials, even in the field of natural polymers. Materials with a wide variety of properties have been realized, and many more. Nanocomposite materials obtained by blending layers of natural polymers and crystalline solid layers (clays or LDHs) offer different property profiles. It can also compete with synthetic polymer materials for packaging on price and performance. Despite the great opportunities for packaging in bio-based nanocomposite materials, it is difficult to predict future scenarios. At this point, we can only imagine simple, traditional packaging being replaced by multi-functional, intelligent packaging. Next-generation packaging materials can meet the preservation needs of fruits, vegetables, beverages, wine and other foods. Adding appropriate nanoparticles makes it possible to produce packages with stronger mechanical, barrier, and thermal performance. For food safety, the nanostructured materials keep out bacteria and microbes. Nanosensors embedded in the package warn consumers when food has spoiled**.**

Using the Multiple Chips (Nanobiosensors) for Labeling Products

Biodegradable Sensors in Food - Electronic Tongue Technology Sensors change color when pH changes due to contamination or spoilage. With regard to the food industry, nanotechnology uses biomolecules such as sugars and proteins as target-recognition groups for nanostructures that can be used, for example, as biosensors in food (Charych *et al.*, 1996). Such biosensors could serve as detectors for food pathogens and other contaminants, and as devices for tracking food. Nanotechnology is also useful in encapsulation systems for environmental protection. Additionally, it can be used to design food ingredients such as flavors and antioxidants (Imafidon and Spanier, 1994). The aim is to improve the function of such ingredients while minimizing their concentration. More research will be done on delivery and controlled release systems (Lawrence and Rees, 2000). Some applications of nanobiosensors include: virus detection with antibody sensor arrays on self-assembled nanoscale block copolymer patterns, detection of food-borne toxins with multifunctional nanoparticles, nanocomposites for detection of pore-forming toxins. Development and Characterization of Materials, Molecularly Imprinted Polymers and Insect Viruses for Plant Detection.

Now, increasing production efficiency and decreasing post harvest wastage with using the findings of novel scientific researches such as biotechnology and nanotechnology in products, could be counted as the best solution to this problem. Nanotechnology using particular characteristics of nanoparticles can be a very useful technology in all science and industry branches. Nowadays, a lot of usages of nanotechnology in agricultural sciences have been established. In relation with extension of horticultural products shelf life, nanotechnology can help us in some grounds, e.g. controlling growth and development of micro organisms, introducing a new generation of packaging coverage's (Films) and controlling influence of gases and the harmful rays (UV), increasing strength, quality and packaging beauty, and using the multiple chips (Nanobiosensors) for labeling products that considered as fundamental step to automated control of storages. The application of nanocomposites promises to expand the use of edible and biodegradable films (Sinha Ray and Bousmina, 2005). Nano-composites also offer extra benefits like low density, transparency, good flow, better surface properties and recyclability. In recent years, nanomaterials have attracted increasing attention because of their potential impact on a wide range of industries and markets (Chen and Hu, 2005). The nanoTiO_2 with light catalyzing capability can oxidize Ethylene into water and CO_2 (Hu and Fu, 2003). Nanotechnology has been widely applied to the food industry. Fuji apples with Nano-SiOx/chitosan preservation agents had good quality according to the research of Li and Wang (2006). Green tea, with nano-packing, had better maintenance of vitamin C, chlorophyll, polyphenols and amino acids than with normal packing (Hu and Fu, 2003).

Applications of nanotechnology in precision agriculture

Delivery of fertilizers

The amount of fertilizers that are used to produce food has increased significantly in recent years, but they can have many harmful effects on the beneficial soil microflora. Most fertilizers are unavailable to plants due to runoff and resulting pollution (*M.A. Wilson et* a)l . Nanomaterials can help solve the problem of slow release of fertilizers.Nanoparticles have a higher surface tension than conventional surfaces, which means they hold the material more strongly and slow down the release of the fertilizer over time(*D. Santoso et al 1999*),. Nanocoatings can protect larger particles from being harmed by the environment.

Chemical fertilizers

Urea fertilizer use has increased by 29% since the green evolution era in India. Increased food production through the use of chemical fertilizers is responsible for 80% of the increase in atmospheric nitrogen dioxide (a greenhouse gas), which leads to increased atmospheric temperature and contributes to global warming.But most of these fertilizers are lost as runoff or volatilization, and it is estimated that about 40-70% of the nitrogen, 80-90% of the phosphorous, and 50-70% of the potassium used in fertilizers is lost to the environment and it cannot be absorbed by the applied plants which causes the loss of the state treasury and the environmental pollution as well (M.E. Trenkel 1997, *A. Ombodi* 2000).A modern approach to fertilizing plants is to use nanocoated urea or other chemical fertilizers.The stability of the nanocoating helps to reduce the rate of dissolution of the fertilizer, which allows for a slower, sustained release of coated fertilizer that is more efficiently absorbed by plant roots. Recent studies have shown that the use of slow release fertilizers can help to reduce fertilizer use while still providing the benefits of fertilizer.Slow release fertilizers with a sulfur coating can be especially beneficial to areas with sulfur deficiencies *N.R. Brady*(1999), *D. Santoso* (1995). Nano-coated urea and phosphate and their sustained release will be beneficial to meet soil and plant needs as most of the soil in India is deficient in these macronutrients, especially nitrogen. Many natural and synthetic polymers have been used for this sustained release fertilizer.Chitosan nanoparticles (78 nm) were shown to be effective for the slow release of NPK fertilizer. Kaolin and biocompatible polymer nanoparticles also have potential applications (*E. Corradini 2010*).

Nanofertilizers help to prevent fertilizer nitrogen and phosphorus from being lost, and to avoid unwanted nutrients interaction with microorganisms, water, and air (S.E. Emadian*)*. Uptake of nutrients from soil by plants can be maximized by using nanofertilizers.. A silicon-based fertilizer used to increase plant resistance as silicon dioxide nanoparticles can improve seedling growth and root development S. Hutasoit *et al* (2013). To increase food production, non-toxic titanium dioxide or titanium can be used as additives in fertilizers. Additives in fertilizers can cause water retention, which can lead to problems such as leaching and denitrification.. The adsorbents zeolite, halloysite, montmorillonite and bentonite nanoclays have been used to develop nitrogen fertilizers with controlled release properties where purification of nanoclays other than zeolite is a costly affair. The preparation of chitosan nanoparticles with polymethacrylic acid (PMAA) has been reported to load NPK fertilizer.The stability of colloidal suspension chitosan polymethacrylic acid (CSPMAA) was found to be higher with addition of nitrogen, potassium and phosphorous, due to the higher anion charge of calcium phosphate than the anion charge of potassium chloride and urea.The dispersion of CS-PMAA with 500 ppm nitrogen was higher in stability compared to phosphorous.Over 500 ppm nitrogen, a decrease in positive charges occurred in the colloidal dispersion of CSPMAA due to the presence of negative groups of urea molecules. For dispersion with potassium, the stability of the solution has been confirmed with the addition of 400 ppm. This showed the presence of Cl^- ions (from KCl) which did not affect the stability of colloidal dispersion with the addition of up to 400 ppm Y. Wu(2006) C.L. de (2006) and M.R. de Moura (2008)

Nanotechnology in safety of horticultural produce

Nanotechnology can help meet the growing consumer demand for safe, high-quality food and meet strict government food safety regulations. Nanotechnology holds promise for improving sensors that can detect spoilage and changes in product quality. To ensure food safety, scientists at the Good Food Project have developed wearable nanosensors that detect chemicals, pathogens and toxins in food in real time (Tiju and Mark, 2006). Food can be analyzed for safety and quality at control points in the supply chain. For example farms, slaughterhouses, in transit, warehouses or warehouses, processing plants or packaging plants**.** This avoid**s** the very time-consuming and expensive alternative of sending samples to a lab. Devices are currently being developed that **use** DNA biochips to detect pathogen**s.** This technique can also be used to determine the presence of various types of harmful bacteria and fungi that affect fruit. In addition, the development of microarray sensors that can identify pesticides in fruits and vegetable**s is** planned. Careful selection of appropriate ingredients and packaging techniques can preserve product quality and freshness **for** the required period of marketing and consumption (Stewart et al., 2002).

Nanocomposite materials obtained by mixing layers of natural polymers and crystalline solid layers (clays or LDHs) offer different property profiles. It can also compete with synthetic polymer materials for packaging on price and performanc**e.** Physical properties of normal packaging and nanopackaging materials have been reporte**d** by Li et al. (2009). Nanotechnology **is** widely used in the food industry. Nanopackaged green tea retained better vitamin C, chlorophyll, polyphenols, and amino acids than regular package (Hu and Fu, 2003). It helps reduce tea packaging associated with processed foods and aids in preserving perishables, extending shelf life.Nanocomposites include low density, transparency, good flowability, excellent surface properties, There are also additional benefits such as In recent years, nanomaterials have received increasing attention due to their potential impact on various industries and markets (Chenand Hu, 2005). Nanolaminates are very thin food-grade films (1-100 nm/layer) with physical or chemically bonded dimensions, composed of two or more layers of materials with nanometer-scale dimensions. . Due to its advantages in producing edible films**,** nanolaminates have many important applications in the food industry. Edible films are present in a wide variety of foods, including fruits, vegetables, meat, chocolate, candies, baked goods, and French fries (Rhim, 2004).Colloids are stable systems of matter containing small particles dispersed throughout. is. Associative colloids are colloids in which particles are made up of smaller molecules. Surface antimicelles**,** vesicles, bilayers, reverse half-cells, and liquid crystals are all examples of associated colloids. The main drawback of associative colloids is that they affect the taste of the material and can spontaneously dissociate upon dilution.

Risk Associated with Use of Nanomaterials (NMs)

Increase in the concentration of nano particles indicated by physiological alterations such as decreased Chl content, deterioration of photosynthetic activity, induction of oxidative stress, and inhibition of growth (Barhoumi et al., 2015). Phytotoxic effects of NPs are also carried out by their direct binding with DNA that has been shown to cause deformation and nicking of the strand that adversely affects stability and function of the molecule (Zhao et al., 2005).

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