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Review article

Nano-technology applications in fruit trees orchards

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Abstract

Global challenges from increasing population with decline food productivity and scarcity of water and soil resources, reaching to global climatic changes all these factors encourage several researchers to focus on innovation solutions and new generation of technology such as Nanotechnology. Nano-technology considered type of science that deal with so tiny size of material ranged from 1 to 100 nanometer. With this nano-scale size material gained novel properties comparing with original form for the same material these phenomena attributed for hug specific surface area for nano-particles. In regarding to utilize Nano-technology in agriculture sector, it plays important roles in different sides as a real revolution in current era. For instances, nano-technology was used in producing fertilizers which called nanofertilizers, producing nano-pesticides, coating, water treating, increasing water usage efficiency and packaging fruit such as nano-chitosan as antimicrobial film for food packaging due to its fundamental antimicrobial and edible properties. Besides, nano-technology facilitates gene transfer and insertion genes into targeted plant cell with using Mesoporous silica nanoparticles (MSNs) and silica nanoparticles. Also, nan-technology has contribution in cloning fruit seedlings particularly to eliminate contamination in tissue cultures and to enhance in vitro explant development through improving uptake nutrients from culture medium. At the final, it can be concluded that, nano-particles looks like a weapon that has double edges, whereas can be useful and harmful in the same time depending on the way of its' uses. Through this review, authors tried to increase awareness with the importance and summarized contribution of nanotechnology in agriculture sector to increase usage efficiency of available resources, minimizing environmental pollution through decreasing amount of used agrochemicals, from other side, exploring risks of utilizing of nano-materials in agriculture activities and highlight on precautions that should be taken during dealing with nano-materials.

Introduction

Technical innovations play an importance role to overcome global challenges for example increasing population growth rate, climate varying from time to time and the limited natural resources (soil and water). Under umbrella of these global challenges, most efforts go toward and focus on new generations of technology particularly in agriculture sector. Which, its role should extend to enhance nutrient use efficiency (NUE), new generation of smart delivery pesticides, reducing agricultural production loss and raising water use efficiency (WUE). One of these generations is Nano-technology that becomes as a new revolution whereas some people considered it as Sixth revolutionary technology in the current era after the Industrial revolution, Nuclear Energy revolution, Green revolution, information technology revolution and Biotechnology revolution.
Prasad *et al.* [1] showed that, in the year 1959 Richard Phillips Feynman was the first scientist indicated to nanotechnology in his lecture with "Plenty of room at the bottom". During an International Conference on Production Engineering-1974- at the Tokyo, Nori Taniguchi in 1974 described ultrafine machining used in synthesis of a material at nanoscale. His work was concerning with evaluating the mechanisms of machining hard and brittle materials such as quartz crystals, silicon, and alumina ceramics by ultrasonic machining [2].
Many believe that such Nano-technology will be an effective tool to narrow gap between food production and increasing world demand on food as well as cover a wide spectrum of advantages related to environment, human health and economic [3].
Nanotechnology may be defined as new installation of material in new forms within Nano scale from 1-100 nanometers associated with superior and effective properties (physical, chemical, biological, mechanical, magnetic, optical, electrical...etc.) [4].
Nowadays, nanotechnology gained a great obsession of attention of late across the globe due to its role in opening up a wide array of opportunities in different field sciences

and its massive advantages. Word of "Nano" came from the Greek and it means "dwarf." The abbreviation indicates very tiny dimensions that are within range of one meter divided to billion part. This scale is called colloquially nanometer scale, or Nano-scale. Gathering two hydrogen atoms approximately equal 1 nanometer.

Recently, nanotechnology has made remarkable contribution in field of technology by means of its vital applications. It is involved in different branches of sciences i.e chemistry, biology (i.e. Agriculture: fertilizers, pest control and postharvest packaging etc.), physics, materials science, medicine, nuclear science and engineering science.

There are many applications referred to nanotechnology involved in several agricultural processes (i.e. fertilization, irrigation, pest-controlling, packaging, postharvest and processing). The utilization of nanotechnology in agricultural field has several positive impacts on environment [5].

Implementation of Nanotechnology in agricultural practices could play an essential role for raising productivity and for investigation trend in agricultural applications.

Whereas, Ragaei and Al-Kazafy [6] mentioned that potential utilize and positive impacts of nanotechnology are tremendous. These impacts include maximizing agricultural productivity involving nanoporous zeolites for raising efficient usage both of water and fertilizer by controlling their releasing.

Also, Raliya*et al.* [7] interpreted that Nano-particles of materials are used for its wide surface area which in role induce high reactivity, effective catalyst of plant metabolism, better penetration into the cell and increase plant activity.

Mechanisms of synthesis of nano-particles

There are several available techniques to synthesize different types of Nano-materials (nanoparticles). However all these techniques followed one of the three main techniques: physical, chemical or biological method.

Biological

Biological (or green) techniques mainly based on down-top strategy to create NPs. The biological methods of depend on biological systems such as fungi, bacteria, yeast actinomycetes, Plants extracts etc to synthesis NPs. Nanoparticles processing would support to remove severe processing conditions, by enabling the synthesis at physiological pH, temperature, pressure and at the same time, at low cost. Nano-Silver is one of nanoparticles produced through biological methids.

Chemical

Nano-particles synthesis belong to down- top strategy. These chemical methods implemented several techniques such as chemical vapor sedimentation, sol-gel, hydrothermal route, microemulsions, polymer route and other precipitation processes. Urea modified hydroxyapatite nano-particles represented sample for nano-compounds produced via chemical methods.

Physical

Generally, physical techniques belong for top-down way whereas particles with huge size will be converted into nano-scale particles by using different physical techniques for instance: pressure, high energy radiations, thermal energy or electrical energy to cause material abrasion, melting, and condensation. Moreover, the most advantages of these techniques that there is no solvent contamination risk and less economically wastes during conversion processing. Nano-zeolite and nano-clay are examples produced through physical methods

Mechanical methods include mechanical grinding, high-energy ball milling, mechanical alloying (MA), laser, Ultrasonic and reactive milling.

Nanomaterials are being a good motive to new application of the nano-technology because they induce novel optical, electric, hardness, elasticity and/ or other properties.

Nano-materials with its tiny structure and features at nano-scale may be existed in the structure of clusters, superfine films, several layers and nano-crystalline compounds. Nano-materials often have properties differed than original form for instance, nanocrystalline copper is five times harder than ordinary copper and more elastic.

Application of nano-technology in fruit trees orchards

In developing countries a marketable abundant of agricultural products are the most effective factor which influences the economic development of countries. In this context, Green revolution in 1960's came to narrowing gap between increasing demand on food due to population growing rate and food chain production. The term of Green Revolution, permitted developing countries to face continual increasing food demand by increasing food production through using super productivity varieties of seeds, advanced agricultural practices (high densities applications, irrigation system, fertilization system), expanding cultivated area and substantially increasing use of chemical inputs (such as fertilizers and pesticides). Moreover, excessive applications of agro-chemicals (fertilizers and pesticides) have become essentially and necessary to secure high productivity and supplying foods. Such types of agriculture practices have the great negative impacts on the environment and consumer health [8]. For the aforementioned above, nano-technology applications particularly that concerning fertilizers, pesticides and other purposes (packing, detecting plant infection and monitoring environmental condition) gain great sound to avoids excessive usage of ordinary agro-chemicals.

Nano-fertilizer

Since wide scale uses of fertilizers results in a serious incline in soil fertility, soil microorganisms activity, plants, mineral cycles, and detrimental effects on food production through changes ecosystems resulting in inducing continuously mutations risk in coming generations of consumers. Significant ongoing research in nanotechnology has enhanced techniques for mass production of nano particles of physiologically important metals which can potentially develop fertilizer formulations for increased its' efficiency and by minimizing nutrient loss. Nano- fertilizers may lead to increase the nutrient uptake efficiency by mechanisms such as targeted delivery, controlling and extending duration of viability of nutrient in root zone. Based on environmental inducers and biological demands the active ingredients will be released. In recent studies, authors carried out lab scale investigations and concluded that new generation of fertilizers can enhance crop productivity by enhancing the rate of seed development and germination, seedlings growth performance, photosynthesis process rate, nutrients uptake and metabolic processes and (particularly carbohydrate and protein) synthesis.

Nano-nutrient system is conducted to deliver nutrients in a regulated pattern in correspondence with the crop requirements and development stages thereby nutrients use efficiency may be developed without side effects [9].

Also, Heller and Atkinson [10] and Subramanian and Sharma [11] illustrated that nano- scale makes fertilizers nutrients more available to crops for long time than conventional fertilizers form and resulted in raising nutrient use efficiency and reducing environmental contamination with leached minerals.

From other view, nanofertilizers may be used to minimize nitrogen loss due to leaching, emissions, and long-term reaction with soil microorganisms. They may permit for selective release related to time or environmental conditions. Nanofertilizers allowed minimizing side effects and negative impacts of conventional fertilizers by controlling its release.

Georgia *et al.* [12] reported that, the main and important application of nanotechnology in agricultural sector is concerning with nano-fertilizers. Nano-fertilizers are nutrient carriers of nano-scales qualified for carrying nutrient ions due to their hug specific surface area and control its release steadily that meet crop needs [13].

Several techniques may be used to encapsulated fertilizers such as coating with nanoparticles, covered with a tiny protective film, or delivered as emulsions or nanoparticles. Nano-particles with a higher specific surface area and reactivity of nano-fertilizes may have a positive effect on nutrient solubility, diffusion and hence availability to plants [14].

In Egypt, Roshdy and Refaai [9], showed that, nano-NPK had a promising impact on growth rate, yielding and different fruit parameters of (Cultivar Zaghloul) date palm comparing with conventional NPK under Minia conditions. Moreover, these positive impacts of nano-NPK produced from low doses in comparison to conventional NPK which revealed that improving nutrient use efficiency (NUE) in nano-form. Besides, they attributed increasing in NUE for another reason whereas through nano-NPK, nutrients will be delivered for plant in a regulated pattern based on crop needs.

In Iran, Davarpanah *et al.* [15] studied effect of the foliar nanofertilizers of zinc (0, 60 and 120mg Zn L^{-1}) and born (0, 3.25 and 6.5 mg BL^{-1}) as a single spray before full bloom at rate of 5.3 L/tree, on productivity and fruit quality of pomegranate (Cultivar Ardestani). Their results showed increments in concentrations both microelements in August, reflecting the improvements in tree nutrient status. Also, spraying nano-Zn and nano-B led to increase in pomegranate fruit yield, as result of increasing fruit number per tree. Moreover, a significant improvement was noticed in fruit quality, including T.S.S., maturity index, juice and deceases in T.A. (Total acidity).

Also, Davarpanah *et al.* [16] conducted an experiment during (2014-2015) to study effect of spraying nitrogen fertilizer in nano-form (nN) and urea on pomegranate fruits Cultivar Ardestani. Five treatments (four replicates/ treatment) were applied twice at full bloom and one month later as the following two treatments for nN (1.3 & 2.7g N/tree $\approx$ 0.9 and 1.8kg/ha), two treatments for urea (24.4 and 48.8g/tree $\approx$ 16.3 and 32.5 kg/ha) and the last one is control (trees sprayed with water). Obtained results indicated that spraying N fertilization (whether nN or urea form) increased fruit yield and number of fruits per tree. Applied nN at (1.8kg/ha) resulted in producing the highest yield and number of fruit/tree. Meanwhile control trees produced the lowest yield and fruit number /tree. Regarding to comparison between nN and urea treatments, results showed that spraying nN at 1.8kg/ha or urea at (16.3kg/ha) produced the highest fruit length, TSS, acidity, sugar and deceased anythocyanins. Applying nitrogen led to increment in leaf content f N, however the rest of nutrients (P, K, Mn, and Zn) did not affected. Finally, spraying nN (1.8kg/ha) gave results very close to that obtained by applying urea at 16.3kg/ha as foliar which mean there is possibility to protect environments with reducing amount of added fertilizer and improving fruit quality by utilizing nano-fertilizers.

More efforts had been carried out in Egypt whereas in this trend, Zagzog and Gad [17] reported that, spraying mango trees (Ewasy and Zebda) with nano-zinc at 1g/l before flowering is recommended for improving yield and fruit quality as well as raising resistance of malformation.

In addition, Hagagg *et al.* [18 & 19] mentioned that nanofertilizers have a positive effect on growth performance of olive seedling. Moreover, they showed that replacing half of recommended dose of mineral fertilizers (0.5g/seedling as soil application) with nano-fertilizers as foliar application at (0.2%) three times (June, July and August) enhanced most of recorded vegetative growth parameters and without any deficiency symptoms on "Aggizi" olive seedlings. Also, they concluded that nano-NPK has a promising future and it can be safely alternative source for fertilizers.

Mustafa *et al.* [20] reported that growth parameters (leaf fresh weight, leaf dry weight and leaf area) were increased when Nano-fertilizes were applied at high levels (300 & 400 ppm) as foliar application on "Sultani" Fig cultivar compared with conventional fertilizer (500ppm). In respect of nutrient status applying nano-NPK at (300 & 400ppm) recorded similar levels of nutrient that recorded with conventional NPK at 500ppm which may reveal that there is possibility to reduce added fertilizers without negative impact on growth and nutrient status in plants. Nano-NPK resulted in increasing in activities of enzymes (peroxidase and polyphenol oxidase) in comparison with conventional NPK. Current study confirmed the benefits of applying Nano-fertilizers in growth performance and environmental protection by reducing added amounts of minerals.

Hafez *et al.* [21] treated Washington Navel orange trees with conventional potassium (K_2O) and nano-potassium nanocapsulated biodegradable polylactic acid (K-PLA) or in their mixture (three times in the year) at different levels (75% K_2O+25% K-PLA, 50% K_2O +50% K-PLA and 25% K_2O+75% K-PLA) during two successive seasons 2015 and 2016 in private orchard located at El-Kalubia Governorate to evaluate the dual benefit (yield and fruit quality). K-PLA can stabilize K and significantly enhanced yield and coloring percentage than uploaded K (K_2O). Both treatments decrease juice acidity %. Also, mixture (upload K + K – PLA) markedly enhanced both of TSS, V.C. and the highest enhancement was achieved with formulation (25% K_2O+75% K-PLA) meanwhile the lowest enhancement was recorded with formulations (75% K_2O+25% K-PLA).

Abdelhak [22] showed that adding CNTs at rate (0.6%) with 80% of recommended dose of nitrogen (50gN/vine/year) improved most of vegetative growth parameters, nutrients status and measured fruit quality comparing with other combination of CNTs (0.2, 0.4, 0.6%) and nitrogen (40, 30, 20g N/vine/year). Meanwhile, treating flame seedless grapes with 0.4% (T4) of Nano-zinc produced markedly higher vegetative growth parameters, nutrient content and recorded fruit quality characters in comparison with other treatments (T1 Tap water only (control), T2 zinc sulphate at 565 ppm, T3 zinc EDTA at 140 ppm, T5 nano zinc at 0.8 ppm and T6 nano zinc at 1.2 ppm.)

Finally Baruah and Dutta [23]; Fernandez *et al.* [24]; Remya*et al.* [25]; Sheykhbaylou *et al.* [26]; Mousavi and Rezaei[27]; Bozary [28]; Ekinchi*et al.* [29]; Refaai [30] and Sabir *et al.* [31] confirmed the positive impacts of applying nano-nutrients on growth performance and productivity of crops Versus conventional NPK fertilizers.

Hence, nanotechnology has a highly potential to play a good role in sustainable agriculture, especially in developing countries [23].

Application of nano-technology in pesticides production

Pesticides considered a second backbone for agro-food chain around the world by making a barrier between crops and pathogens thereby enhancing agricultural production. Basically, the usage of agrochemical (particularly pesticides) increased after the launched the Green Revolution which helped developing countries to face the major problem of food crises. Although, the implementation of pesticides in agriculture practices served as a backbone but still there is serious negative effects and harmful impact on both of environment and consumer health.

Much efforts showed a strong relationship between the extent of pesticide used and symptoms of negative side effects on farmers due to exposure to agrochemical (burning/stinging of eyes, not cleared vision , skin redness/itching , excessive sweating- increasing in breath ate and dryness sore throat) in different regions over the world specially in developing countries.

Also, Ragaei and Al-Kazafy [6] indicated that conventional police such as integrated pest management (IPM) employed in agriculture are appeared inefficient and using agro-chemical (pesticides) have harmful impacts on environments that contributed in decrement in soil fertility. Thereby, nanotechnology would be considered as an efficient alternatives technique for the management of agro-chemical (i.e. insect pests) in agriculture without negative side effects on environment.

Moreover, to eliminate such the negative impacts of convention pesticides application, utilizing nanotechnology in this area attracted great attention over the world. Whereas, capsulated pesticides inside nanoparticles (carbon, silver, silica and alumino-silicates) may lead to be timed-release or it may be released under specific environmental trigger. Association smart delivery system with applying agrochemical (i.e. herbicide and other agrochemicals) could be resulting in valuable benefits related with crops yielding and less injury to environment and human health.

Also, Ragaei and Al-kazafy [6] showed that nan-technology contributes in development of advanced pesticides within nano-scale which allowed to control releasing active compound. The efforts are focused on successful application of these nano-pesticides on crops and their efficiency and availability enhancement and decrement of environmental pollution and workers exposure [32]. In this context, new lines of agro-chemical were synthesized. The most promising achievement is the employing of nanotechnology to enhance the active compound in a mixture in order to protect active materials from unwanted reactions due to varying factors like temperature, air or light. Nanotechnology as every new science has protesters who working on focusing on negative sides more the benefits sides [33]. There is a great awareness respecting the nonmaterial becomes a double edged weapon. In addition, they emphasized that potential usage and impacts of nanotechnology are tremendous. These include nanocapsules for herbicide delivery and vector and pest management and nano-sensors for pest detection.

Moreover, Routray *et al.* [34] mentioned that application of nanotechnology in crop protection brings tremendous positive impacts in management of biotic stress by controlled and targeted delivery of agrochemicals. Nanoparticles, nanoemulsions, nano suspensions and nanocapsules have wider usage as insecticides, insect repellents, herbicides and antifouling agents.

New generation of pesticides such as Ag, Cu, SiO_2, ZnO based on nanostructure show wide-spectrum pest protection efficiency, minimizing pollution in water, soils and environment comparing with ordinary pesticides. The Zn is an essential element for plants and is poor in soil this makes Zn metal as a valuable target to developing Zn in nano-scale as double edges weapon (combat pest and useful for plants). ZnO NPs are not expensive and safe. They can be utilized in different fields such as anti-cancer, anti-diabetic, anti-bacterial, anti-fungal and agrochemical industries. The antifungal activity of ZnO in nano-form to face plant pathogen *Fusarium graminearum* have been demonstrated by [35]. The other potential option could be silver. The silver (Ag) is used in the field of the biological system, living organisms, medicine, plant management, pest control and agricultural aspects with advanced efficiency and activity are the ideal target of the green technique linked to antibacterial, microbial, fungal, larvicidal, pesticidals, anti-inflammatory, antiplatelet activity, anti-angiogenesis and anti-viral activity [36, 37 and 38]. The metal in nano form has an advantage of stability, slow kinetics which can be scale up for large quantity, performed at room temperature and generation of eco environmental byproducts [39]. Thus nanostructure of bio pesticide may be the best alternative for enhancement of pest-control weapons for unwanted insect.

In addition, Ragaei and Al-Kazafy [6] illustrated the mechanism how the nano-pesticides based on the its' nano-scale size and shape that permit the manipulation of nanoparticles thus affected by their size, shape and orientation for desired reaction with the particularly tissues. Besides, nanoparticles possess different physical, biological and chemical properties according to its new size and structure. It is well known that many insects have ferromagnetic materials in different parts of its body (head, thorax and abdomen) which play role as geomagnetic sensors. Nano-pesticides may be consisted of organic ingredients (such as polymers) and/or inorganic components (such as metal oxides) in new forms (e.g. particles and micelles). The goals of these nano-form are (besides other pesticides): 1. Increasing the apparent solubility of poorly soluble active ingredient. 2. Controlling the release of active compounds that in resulting in protecting the active compound against unwanted interaction with environment conditions.

Nanoparticles in agriculture play an important role as 'magic bullets', embedded insecticides, fungicides, herbicides, chemicals, or genes, which designed for specific plant parts or organisms to release their active gradients. Nanocapsules may facilitate effective insertion of herbicides through cuticles and tissues, providing slow and constant release of the active substances.

Nanotube filled with aluminosilicates can attached to plant surfaces, while active nanotube material can transfer to the surface hair of insect pests and finally go into the insect's body and doing its physiological functions [40].

Rouhani*et al.* [41] reported entomotoxic effects of Ag and Zn nanoparticles as a conventional insecticide.

Aforementioned encouraged numerous chemical companies to extend in producing an efficient nanopesticides and nanohericides at nano scale. One example for these efforts is utilized of Alumino-Silicate nanotubes with effective ingredients. Pesticides via Encapsulation, Pesticides containing active ingredients in nano-form can be purchased in the market, and tremendous studies have been conducted on such this new generation of pesticides to clarify its advantages [42].

Delivery of pesticides is either provided as "deterrent" treatment or is release the active compound and provided it once the disease organism has multiplied and symptoms are evident in the plant or animal [42].

Nano silica-silver

Silicon (Si) also, is well known to be absorbed by plants to reinforce plant disease resistance and stress resistance. The pathogens destroyed from the infected leaves 3days after applied it as foliar application and the plants remained in healthy status. Also several studies concerning the 'effective dosages' of nanosized silica-silver on deactivation of growth of many fungi; and found that, *Pythium ultimum*, *Colletotrichum gloeosporioides*, *Botrytis cinere* and *Rhyzoctonia solani*, showed 100% growth inhibition at 10 ppm of the nano-sized silica-silver [43].

Application of nan-technology in other purposes of agriculture

Nano-particles and cloning of fruit trees

Rostami and Shahsavar [44] showed that sterilizing olive explants is the big challenge that faced in vitro cloning olive species. In this term, they studied the potential of nano-silver for decreasing contamination in olive's in vitro cultures. Their results showed that submerge olive explants in nano-silver was so effective tool to control the contamination however this treatment caused high score of injures for olive explants. Meanwhile, supplemented olive culture medium with nano-silver at low concentration (4mg/L) was significantly effective way for disinfecting explant internal contamination without any observed harmful effects. These results could be attributed for ability of nano-silver to release its so tiny particles which destroyed not only bacterial and fungus but also, its' effect extend to viruses [45].

Taha *et al.* [46] investigated effect of carbon nanotubes (CNTs) on in vitro of date palm. Carbon nanotubes (CNTs) concentrations were studied at 0.0, 0.05 and 0.1 mg/l. Obtained results showed that CNTs enhanced all stages of in vitro propagation of date palm. Callus fresh weight showed an increment when culture medium supplemented with CNTs at 0.05 mg/l. In respect to embryogenesis stage, CNTs was enhanced number of germinated embryos and root number. Also, Carbon nanotubes produced a significant increment for shoot length, leaf number in elongation stage, and root parameters (root number, root length, plantlet length and hairy roots).

Gaafar *et al.* [47] showed that when carbon nanotubes implemented in jojoba in vitro culture medium, generally, growth of explants was enhanced. Moreover, CNTs enhanced shoot multiplication rate; as leaf number as well as callus degree compared with the control and activated charcoal (AC). CNTs at low rate (0.002g/l) significantly increased antioxidant activity, phenolic, flavonoid and tannin contents compared with its other used concentrations (0.2 and 0.02g/l).

Nano technology for postharvest packaging

Microorganisms (fungi, bacteria, and other organisms) caused much losses for fruit and vegetable. Fruits are very susceptible for spoilage due to its low pH, highly moisture contently, organic and saccharides compounds meanwhile, vegetables less acidic and they are attacked usually by bacteria [48 and 49]. Although it is very difficult to evaluate the full extent of postharvest losses due to decay (i.e., attack by microorganisms and physical damages), it is well known that these losses are significant [50].

The simple postharvest practices (e.g., selection of suitable harvest timing by maturity indices, cleaning of the product, sorting, packaging, quick cooling and good refrigerated storage and appropriate transportation and distribution) has been successful for small scale when they are modified. However, these practices do not be effective to preserve fruits against spoilage during postharvest [51]. Chemical treatment is one of the postharvest techniques that are normally used before and after harvest to prolong shelf life and reduce food decaying [52].

Conventional materials used widely in fruits packaging, most of them is not degradable material thereby representing a serious problem to get rid of solid waste.

From other view, increasing demand for fresh fruits and vegetables with good quality and more nutritive value support the food industry to develop novel and perfect methods for preserving food quality and prolong shelf life [53]. In this context, much efforts and more progress in technology of science, Nanotechnology has been detonated as the new generation of revolution in several industries, including food processing and packaging. Anti-microbially active packaging is advanced generation of nano food packaging based on metal nano-composites which are made by combining metal as nanoparticles into polymer films [54]. In this context, Silver nanoparticles can be coated with polymeric materials such as PVC, PE, PET while polymerization occurs. Silver nanoparticles have desired effects on pathogens, bacteria, viruses and fungus and are employed as an effective and safe packaging pot. Such packaging materials in nano-form are 100 times more secure than the normal one for the storage of juices, other agri-products [42]. Also, Liau *et al.* [55] reported that the most common nano-composite used as antimicrobial film for food packaging are based on silver ions, which is well known for its strong effects against a wide range of microorganisms. Moreover, Damm *et al.* [56] that mentioned Silver nanocomposites have been produced by several researchers and their antimicrobial effectively has usually been reported. Li *et al.* [57] indicated that with nano-SiOx/chitosan better quality of Fuji apple fruit can be kept for long period comparing with the conventional strategy.

Also, Emamifar *et al.* [58] reported that using packaging material containing silver and ZnO nano-particles reduced microbial growth rate in organ juice and prolong shelf life of fresh juice of orange up to 28 days without negative side effect on sensoria parameters.

In addition, Zandi *et al.* [59] showed that strawberries as several fruits and vegetables are exposed to quality changes after harvesting and weight losses may be reached to 40% during storage. Also, they indicated that using nanocomposite packaging (nano-silver based on polyethylene and polypropylene and nano-silicate based on polyethylene and polypropylene) prolonged shelf life and maintained fruit quality parameters of strawberry comparing with conventional polymer packaging. Moreover, nano-silicate based polyethylene or based on

polypropylene reduced weight losses more than nano-silver based on polyethylene and polypropylene.
Besides, Yang *et al.* [60] mentioned that there is a significant difference in the amount of acids between nano containers and regular polymer ones for preserving strawberry during storage span. In addition, they reported that strawberry available in nano containers achieve more market-friendly compared to regular polymer containers and [60] attributed these results due to the fact that nano containers hold more humidity and less oxygen enter and leave.
In Egypt, Gad *et al.* [61] investigated impact of using nano-chitosan on shelf life of peach fruits (*Prunuspersica* (L.) Bastch) and its quality. Peach fruits coated with one of the following concentrations (0.2, 0.4 and 0.8) and control under 0±1°C and 90-95% relative humidity for 28 days. Obtained results indicate that, through two successive seasons 2015 / 16, the lowest fruit decay percentages and TSS/acid ratio associated with using nano-chitosan 0.4%. Moreover, the best qualities of peach fruits were resulted from the 0.4% nano-chitosan treatment after 28 days of cold storage. These results supported with what mentioned by Chiellini [62] who defined chitosan as polysaccharide and most frequently used as a base material for forming films and coatings in food packaging due to its fundamental antimicrobial and edible properties. Other study, stated that chitosan was extensively used to protect, improve quality and extend the shelf life of fresh foods [63]. In this term, chitosan coating was used as safe and effective method for extending shelf life of strawberry fruits [64]. Furthermore better control of postharvest rots in citrus fruits attributed to chitosan [65], apple fruits [66], papaya fruits [67] and sweet cherries [68]. In this line, Li and Yu [68] attributed impact of chitosan coatings on extending storage lifespan of fruits to its ability to modify the gas exchange between the outer atmosphere and the internal gas composition, and reduces transpiration rate, water loses and slowed the fruit ripening [70]. The reduction of water loss resulted from using chitosan has been also reported for numerous horticultural commodities such as tomatoes, longan, apples, mangoes, bananas, bell peppers, Peach, strawberries, etc [71 and 72]. Also, Ziani *et al.* [73] referred antimicrobial activity of chitosan has a positively charged amino group which react with negatively charged microbial cell membrane encouraging an increase in their releasing and causing to cell death.

Nanoparticles and gene transfer

Mesoporous silica nanoparticles (MSNs) can reinforce gene transfer into targeted plant cells. MSNs can serve as container for wanted genes to deliver to into plants. MSNs can carry genes and penetrate cell wall. It was found that Mesoporous silica (MPS)/DNA complexes showed enhanced transfection efficiency. These results indicate that MPS can be employed in the future as a potential gene carrier to antigen presenting cells [74].
Also, silica nanoparticles can be used to deliver foreign genetic material into plant cells in a process called transformation. Nanoparticles can be used to carry and release effectors small molecule (estradiol) that induce the expression of genes within the plant cells in a controlled fashion.

Biosensors to monitoring factors involved in agricultural sector

A nanosensor is a device consisting of an electronic data processing part and a sensing layer, this unit can convert a signal such as light, or the presence of an organic substance or gas into an electronic signal. These nano-sensors associated with GPS system for monitoring all needed data and can be distributed throughout the field to monitor conditions.
Nanosensors may monitor soil contaminants, pests, nutrient status, and plant stress due to drought, temperature, or pressure. They may help to increase efficiency by applying inputs only when necessary.
The developed biosensor system is an effective tool for online observing environment conditions. Bio-analytical nanosensors are employed to observe and quantify minute amounts of contaminants such as viruses bacteria, toxins bio-hazardous substances etc. in agricultural systems. Biosensor techniques are currently being developed as mentoring tools for applying in field analysis [75].

Agricultural production precision farming

Precision agriculture means that all agricultural practices controlled by satellite systems such as fertilization, irrigation light, temperature, best time for cultivation and harvesting etc. With such this system farmer will be provided with all required data to avoid adverse effect of climatic changes and other effective factors.
Also, This system including the fine-tuning and more accurate micromanagement of soils; the more efficient and targeted use of inputs; new toxin formulations for pest control; new crop and animal traits; and the diversification and differentiation of farming practices and products within the context of large-scale and highly uniform systems of production [42].

Nanotechnology and water safety in developing countries

Challenges in the water sector in developing countries (specially arid and semiarid regions), Water poor quality and scarcity has been reported as a critical problem comes from increasing population, rapid urbanization, growing industrialization and increasing agricultural activities. Treating water and remediation has been cited as the most critical sector where nanotechnology usages might help in developing countries. Some of the involvements include Nano-membranes for improving quality of water, desalination, and detoxification. Moreover, Nano-sensors may be used for the mentoring contaminants and pathogens. Besides, Nano-porous zeolites, nano-porous polymers, and Nano-clays for water purification, magnetic nanoparticles for water treatment and remediation and TiO2 nanoparticles for the catalytic degradation of water pollutants.

Nano-filter for water treatment techniques including carbon nanotubes, nanoporous ceramics, and magnetic nanoparticles may be employed to remove unwanted materials from water and could potentially remove pollutants (pathogens and heavey metals) from water. Also, Nanoparticle filters can be used to treating wastewater whereas it can used to remove organic particles and pesticides from water.

Conclusion

New strategies strongly needed to narrowing gap between production and food demands. Nanotechnology can contribute to enhancing agricultural productivity in a sustainable manner, using agricultural inputs more effectively, and reducing by-products that can harm the environment or human health. On other side Nanotechnology has represented the potential to revolutionize in several aspect of food production for instances nanotechnology involved in production nano-fertilizer, nano-pesticides. Moreover, nanotechnology involved in crop breeding, nano-particles facilitate gene transferee into plans, modifying the genetic constitution and cloning plants. Besides, nanotechnology contribute in producing fruit packages to prevent microbial growing, producing biosensors to monitoring factors involved in agricultural sector. For these purposes, the applications of nanotechnology in agriculture sector can prove to be a big boon. Also, the use of nanotechnology as alternative traditional agrochemicals will lead to reduce environmental pollution.

Nanotechnology can be applied in all aspects of the food chain, both for improving food safety and quality control, and as novel food ingredients or additives, which may lead to unforeseen health risks. Moreover, the nano materials once entered in the environment have the potential to accumulate in the environmental organisms.

Although a lot of information about individual nanomaterials are available, however risk level of many nano-particles is still indefinable, thus the application of these materials is limited due to the lack of knowledge of risk assessments and impacts on human health. Development of comprehensive database and alarm system, as well as international cooperation for regulation and legislation are necessary for exploitation of this technology.

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