NANOTECHNOLOGY FOR PLANT DISEASES CONTROL

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Abstract— **Nanotechnology is going viral and its potential is touted to usher in the second green revolution. Given the increasing world population, it is necessary to use the modern technologies such as bio and nanotechnologies in agricultural sciences. Nanotechnology has been defined as relating to materials, systems and processes which operate at a scale of 100 nanometers (nm) or less Nanotechnology has many applications in all stages of production, processing, storing, packaging and transport of agricultural products. Investments in agriculture and food nanotechnologies carry increasing weight because their potential benefits range from improved food quality and safety to reduced agricultural inputs and improved processing and nutrition. It is presumed that nanotechnology will make agriculture sustainable and profitable by reducing the use of fertilizers, pesticides and water due to their enhanced use efficiency. Nanotechnology can be used for combating the plant diseases either by controlled delivery of functional molecules or as diagnostic tool for disease detection. Therefore a slew of nano-devices and products are being developed for smart delivery of fertilizers, pesticides, growth regulators including nanosensors for real-time monitoring of soil conditions, crop growth, disease attack etc. This would mean enhanced Agriculture production , healthy food softy and security. The possibilities in future as well as some success that have been achieved so far are discussed in this review.**

Index Terms— Nanotechnology, agriculture, food softy and security

I. INTRODUCTION

The first and most important need of every human is needs to food, and food supply for humans associated with agriculture directly and indirectly. Growth of the agricultural sector as a context for development objectives is seen as essential in developing countries. Food security has always been the biggest concern of the mankind. Recent decades have seen even bigger challenges on this front. Modern technologies such as bio and nanotechnologies can play an important role in increasing production and improving the quality of food produced by farmers.

II. What is Nanotechnology?

Nanotechnology is the manipulation or self-assembly of individual atoms, molecules, or molecular clusters into structures to create materials and devices with new or vastly different properties. The definition of nanotechnology is based on the prefix “nano” which is from the Greek word meaning “dwarf”. In more technical terms, the word “nano” means 10-9, or one billionth of something. For comparison, a virus is roughly 100 nanometres (nm) in size. The word nanotechnology is generally used when referring to materials with the size of 0.1 to 100 nanometres, however it is also inherent that these materials should display different properties from bulk (or micrometric and larger) materials as a result of their size. These differences include physical strength, chemical reactivity, electrical conductance, magnetism, and optical effects.

A. Types of nanoparticles

Nanoparticle (NP), in general, is a sub-classification of ultrafine particles with lengths in two or three dimensions greater than 1 nm an smaller than about 100 nm, and which may or rnay not exhibit size-rela ted intensive properties. Broa ly, the types of NPs (Norwegian Pollution Control Authority, 2008) include:

- Natural nanoparticles: Particles with one or more dimensions at the nanoscale originating from natural processes, e.g. soil colloids.
- Incidental nanoparticles: Nanoparticles formed a by-product of man-made or natural processes, e.g. welding, milling, grinding or combustion. ENP , also called "manufactured nanop rt 'c es"): Nanoparticles manufactured to have specific properties or a specific co , posit'on. The ENPs are the ones that are being widely used for various applications and include
- Fullerenes (grouping Buckminster fullerenes, carbon nanotubes (CNTs), nanocones etc.)
- Metal ENPs (e.g. eiemental Ag, Au, Fe)

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- Oxides (or binary compounds when including carbides, nitrides etc.). E.g. TiO_2' Fe oxides.
- Complex compounds (alloys, composites, nanofluids etc., consisting of two or more elements) e.g. Cobalt-zinc iron oxide.
- Quantum dots (or q-dots) are binary or complex compounds often coated with a polymer. They are usually regarded apart due to unique use and composition. Qdots are ENPs that exhibit size-dependent electronic or optical prop erties due to quantum confinement. E.g. cadmium selenide (CdSe) which has light emission peaks that varies according to particle size; green for 3 nm diameter particles, red for 5 nm, etc. Q-dots are used in electronics/experimental biology/ medicine.
- Organic polymers (dendrimers, polystyrene, etc.).

III. Applications of Nanotechnology in Agriculture

The challenge is how to feed the growing population by producing more on a stagnant or shrinking landscape; with lesser input costs and with lesser hazards to the eco-system. (Anonymous, 2009). In between, nanotechnology has proved its place in agricultural sciences and related industries, as an interdisciplinary technology and a pioneer in solve problems and lacks. Nanotechnology has many applications in all stages of production, processing, storing, packaging and transport of agricultural products. The use of nanotechnology in agriculture and forestry will likely have environmental benefits (Froggett, 2009). Nano materials are being developed that offer the opportunity to more efficiently and safely administer pesticides, herbicides, and fertilizers by controlling precisely when and where they are released (Kuzma and VerHage, 2006). Nanotechnology as a new powerful technology has the ability to create massive changes in food and agricultural systems.

Nanotechnology in agriculture and food production, causing the agricultural land returned to its normal position, greenhouse construction with high performance and productivity, prevent extinction and destruction of plants and animals species, and overall nanotechnology provides the efficiency of the agricultural for higher population. In the agricultural sector, nanotechnology research and development is likely to facilitate and frame the next stage of development of genetically modified crops, animal. Best time to achieve the highest yield, best use of fertilizers, irrigation, lighting and temperature are all controlled by these systems. While nano-chemical pesticides are already in use, other applications are still in their early stages, and it may be many years before they are commercialized. These applications are largely intended to address some of the limitations and challenges facing large-scale, chemical and capital intensive farming systems.

The relationship between nanotechnology and agricultural sciences can be investigated in the following fields: Need for security in agricultural and nutritional systems; intelligent systems for preventing and treating of plant diseases; creating new tools for progress in cellular and biological research; recycling waste obtained from agricultural. By using nanotechnology, plant growth ability increases and the best harvest time is determined to achieve the highest performance. In recent decades, agricultural land and soil pollution with hazardous elements and compounds present in industrial and urban wastewater are the most important factors that limiting crop and food production in the world.

Nanostructured catalysts are able to eliminate the harmful components of agricultural ecosystems as a safe. This topic is importance in point of view of physiological plant diseases; eliminate food poisoning, organic products and finally production of healthier products. This nanotechnology application will help to reduce pollution and to make agriculture more environmentally friendly with use of nano filters for industrial waste water treatment, nano powders for gas pollutants treatment, and nano tubes for storage clean hydrogen fuel (Anonymous, 2009).

IV. Nanotechnology in organic farming

Organic farming has been a long-desired goal to increase productivity with low input (that is, fertilizers, pesticides, herbicides among others) through monitoring environmental variables and applying targeted action. Organic farming makes use of computers, GPS systems, and remote sensing devices to measure highly localized environmental conditions, thus determining whether crops are growing at maximum efficiency or precisely identifying the nature and location of problems. By using centralised data to determine soil conditions and plant development, seeding, fertilizer, chemical and water use can be fine-tuned to lower production costs and potentially increase production all benefiting the farmer. Precision farming can also help to reduce agricultural waste and thus keep environmental pollution to a minimum.

An International Federation on Organic Agriculture Movements Position Paper on the Use of Nanotechnologies and Nanomaterials in Organic Agriculture rejected the use of nanotechnology in organic agriculture(IFOAM World Board 2012) However, Nano Green Sciences, Inc. sells a nanopesticide that they claim is organic (The Organic and Non-GMO Report 2009) Canada has banned nanotechnology in organic food production. An amendment was added to Canada's national organic rules banning nanotechnology as a " Prohibited

Substance or Method" (The Organic and Non-GMO Report 2010).

V. Applications of nanotechnology in plant diseases management

Today use of chemicals such as pesticides, fungicides and herbicides is the fastest and cheapest way to control pests and diseases. Also biological control methods are very expensive currently. Uncontrolled use of pesticides has caused many problems such as: adverse effects on human health, adverse effects on pollinating insects and domestic animals, and entering this material into the soil and water and its direct and indirect effect on ecosystems. Intelligent use of chemicals on the nano scale can be a suitable solution for this problem (Perea-de-Lugue, and Rubiales, 2009). These materials are used into the part of plant that was attacked by disease or pest.

Diseases are one of the major factors limiting crop productivity. In crop sciences, nanotechnology can be used for the production of nanocapsules for delivery of pesticides, fertilizers, and other agrochemicals (Jha *et al* 2011). The problem with the disease management lies with the detection of the exact stage of prevention. Most of the times pesticides are applied as a precautionary manner leading to the residual toxicity and environmental hazards and on the other hand application of pesticides after the appearance of disease leads to some amount of crop losses. Nanotechnology for the control of plant diseases is a promising technique in plant pathology either by providing controlled delivery of functional molecules or as diagnostic tool for disease detection, an important step in plant disease treatment (Sharon *et al* 2010). Encapsulation of herbicides could provide improvement in their application. For example Sulfonylurea herbicides are applied through the soil to control Orobanchespp., but several applications are needed to achieve effective control (Joel *et al* 2007). Several studies were conducted using Nano sized particles to control fungal pathogens including such as *Pythium ultimum, Magnaporthe grisea, Colletotrichum, gloeosporioides, Botrytis cinere and, Rhyzoctonia solani, as well as bacterial disease including Bacillus subtilis, Azotobacter chrocecuum, Rhizobium tropici, Pseudomonas syringae* and *Xanthomonas compestrispv.* Vesicatoria (Park *et al* 2006). In Palestine, nanotechnology might be used for the control of several plant pathogens such as powdery mildews on grapevine and olive leaf spot on olive trees. We are interested in using nanosized silica particles and nanocapsules for the control of these diseases. In addition to that incorporation of nanoparticles for formulation and application of bacteria as bioconrtol agents against soil borne pathogens will tested. Some of the nano particles that have entered into the arena of controlling plant diseases are nanoforms of carbon, silver, silica and alumino-silicates. At such a situation, nanotechnology has astonished scientific community because at nano-level, material shows different properties. The use of nano size silver particles as antimicrobial agents has become more common as technology advances, making their production more economical. Since silver displays different modes of inhibitory action to microorganisms (Young, 2009), it may be used for controlling various plant pathogens in a relatively safer way compared to commercially used fungicides. Silver is known to affect many biochemical processes in the microorganisms including the changes in routine functions and plasma membrane (Pal *et al*., 2007). The silver nanoparticles also prevent the expression of ATP production associated proteins (Yamanka *et al*., 2005). In a nutshell, the precise mechanism of bio molecules inhibition is yet to be understood. Thus, use of nanoparticles has been considered an alternate and effective approach which is eco-friendly and cost effective for the control of pathogenic microbes (Prasad and Swamy, 2013). These nanoparticles have a great potential in the management of plant diseases compared to synthetic fungicides (Park *et al*., 2006). Zinc oxide (ZnO) and magnesium oxide (MgO) nanoparticles are effective antibacterial and anti-odour agents (Shah and Towkeer, 2010). The increased ease in dispensability, optical transparency and smooth-ness make ZnO and MgO nanostructures an attractive antibacterial ingredient in many products. Both have also been proposed as an anti-microbial preservative for wood or food products (Sharma *et al*., 2009). Properly functionalized nanocap-sules provide better penetration through cuticle and allow slow and controlled release of active ingredients on reaching the target weed. The use of such nano-biopesticide is more acceptable since they are safe for plants and cause less environmental pollution in comparison to conventional chemical pesticides (Barik *et al*., 2008).

Nanosilver is the most studied and utilized nano particle for bio-system. It has long been known to have strong inhibitory and bactericidal effects as well as a broad spectrum of antimicrobial activities (Prasad and Swamy, 2013). Silver nanoparticles, which have high surface area and high fraction of surface atoms, have high antimicrobial effect compared to the bulk (Suman *et al*., 2010). Fungicidal properties of nano-size silver colloidal solution are used as an agent for antifungal treatment of various plant pathogens; the most significant inhibition of plant pathogenic fungi was observed on potato dextrose agar (PDA) and 100 ppm of AgNPs (Kim *et al.*, 2012).

Among the different diseases, the viral diseases are the most difficult to control, as one has to stop the spread of the disease by the vectors. But, once it starts showing its symptoms, pesticide application would not be of much use. Therefore, detection of exact stage such as stage of viral DNA replication or the production of initial viral protein is the key to the success of control of diseases particularly viral diseases. Nano-based viral diagnostics, including multiplexed diagnostic kit development, have taken momentum in order to detect the exact strain of virus and stage of application of some therapeutic to stop the disease. Detection and utilization of biomarkers that accurately indicate disease stages is also a new area of research. Measuring differential protein production in both healthy and diseased states leads to the identification of the development of several proteins during the infection cycle.

VI. Nanotechnology for detecting plant diseases

A need for detecting plant disease at an early stage so that tons of food can be protected from the possible outbreak; has tempted Nanotechnologists to look for a nano solution for protecting the food and agriculture from bacteria, fungus and viral agents. A detection technique that takes less time and that can give results within a few hours, that is simple, portable and accurate and does not require any complicated technique for operation so that even a simple farmer can use the portable system. The union of biotechnology and nanotechnology in sensors will create equipment of increased sensitivity, allowing an earlier response to environmental changes and diseases.

Technologies such as encapsulation and controlled release methods have revolutionised the use of pesticides and herbicides. Pesticides inside nanoparticles are being developed that can be timely released or have release linked to an environmental trigger. Combined with a smart delivery system, herbicide could be applied only when necessary, resulting in greater production of crops and less injury to agricultural workers. Many companies make formulations which contain nanoparticles within the size ranges of 100-250 nm; they are able to dissolve in water more effectively than existing ones (thus increasing their activity). Other companies employ suspensions of nanoscale particles (nanoemulsions) which can be either water or oil-based and contain uniform suspensions of pesticidal or herbicidal nanoparticles in the range of 200-400 nm. These can be easily incorporated in various media such as gels, creams, liquids among others, and have multiple applications for preventative measures, treatment or preservation of harvested products.

VII. Nanotechnology for crop biotechnology

Nanocapsules can facilitate successful incursion of herbicides through cuticles and tissues, allowing slow and regular discharge of the active substances. This can act as 'magic bullets', containing herbicides, chemicals origins which target exacting plant parts to liberate their substance (Pérez-de-Luque and Rubiales 2009). Torney *et al*. (2007) exploited a 3 nm mesoporous silica nanoparticle in delivering DNA and chemicals into isolated plant cells. Mesoporous silica nanoparticles are chemically coated and act as containers for the genes delivered into the plants; they trigger the plant to take the particles through the cell walls, where the genes are put in and activated in a clear-cut and controlled way, without any toxic side effects. This technique firstly has been applied to establish DNA fruitfully to tobacco and corn plants.

VIII. Saving post harvest plant products:

Antimicrobial packaging of edible food films made with cinnamon or oregano oil, or nanoparticles of zinc, calcium other materials that kill bacteria is being tried. Green packaging using nano-fibers made from lobster shells or organic corn (both are antimicrobial and biodegradable) is also a food safety effort. Improved food packaging needs packaging materials having strength, barrier properties and stability to heat and cold. These are being achieved using nanocomposite materials. Bayer Polymers have produced a nanocomposite film 'Durethan', It is a film enriched with silicate nanoparticles which reduces the entrance of oxygen and other gases, and preserves moisture, thus preventing food from spoiling. Antimicrobial activity can also be imparted through addition of nano-sensors to food packages is also anticipated in the future. Use of nanowheels, nanofibers and nanotubes are being tried to improve

CONCLUSIONS AND FUTURE PERSPECTIVES

It is apparent that the potential of nanotechnology applicants in agriculture is immense. Development in food production that many believed to be either impossible or unforeseeable in the distant future now appears more likely and closer at hand due to nanotechnological interventions. Nanotechnology would help in reducing the use of water, chemicals and will help is enhancing the use efficiency of crop inputs. Nanotechnology has great potential in agriculture as it can enhance the quality of life through its applications in fields like sustainable and quality agriculture and the improved and rich food for community. All over the world, this technology has become the future of any country. One has to be very cautious with any novel technology to be introduced about its probable unforeseen and unexpected jeopardy that could land through its optimistic possibilities. Nanotechnology for the control of plant diseases is a promising technique in plant pathology either by providing controlled delivery of functional molecules or as diagnostic tool for disease detection, an important step in plant disease treatment Though, it is also significant for the future of a state to create skilled prospect manpower for this novel technology. Hence, it is imperative that we develop nanotechnologies that enhance food security and at the same time are safe for the environment. Unless this happens, nanotechnology would lose its credibility and the impressive strides that are presumed to be possible in agriculture and the future of this emerging technology would be in jeopardy.

REFERENCES

[1] **Anonymous, 2009**. Nanotechnology and nano science applications: revolution in India and beyond. Strategic Applications Integrating Nano Science, www.sainsce.com.

[2] **Barik TK, Sahu B, Swain V (2008).** Nanosilica-from medicine to pest control. Parasitolol. Res. 103: 253-258.

[3] **Froggett, S., 2009**. Nanotechnology and agricultural trade. OECD Conference on the Potential Environmental Benefits of Nanotechnology: Fostering Safe Innovation-Led Growth.

[4] **IFOAM World Board** .2011. The use of Nanotechnologies and Nanomaterials in Organic Agriculture. Bonn, Germany: IFOAM World Board; 2011. [Accessed April 19, 2014]. Available from:http://www.ifoam.org/pt/ifoam-position-paper-use-nanotechnologies-and-nanomaterials-organic-agriculture.

[5] **Jha Z., Behar N., Sharma S. N., Chandel G., Sharma D.K. And Pandey M.P. (2011).** Nanotechnology: Prospects of Agricultural Advancement. Nano Vision, (2), 88-100

[6] **Joel D. M., HershenhornJ., Eizenberg H.,AlyR.,EjetaG.,RichP. J.,RansomJ. K., SauerbornJ. and RubialesD. (2007).**Biology and management of weedy root parasites. Horticulture Reviews 33:267–349.

[7] **Kim SW, Jung JH, Lamsal K, Kim YS, Min JS, Lee YS (2012).** Antifungal effects of silver nanoparticles (AgNPs) against various plant pathogenic fungi. Mycobiology 40:53-58.

[8] **Kuzma, J.R. and P. VerHage, 2006.** Nanotechnology in agriculture and food production: anticipated applications. Project on Emerging Nanotechnologies, One Woodrow Wilson Plaza 1300 Pennsylvania Ave., N.W. Washington, DC 20004-3027.

[9] **Pal S, Tak YK, Song JM (2007).** Does the antibacterial activity of silver nanoparticles depend on the shape of the nanoparticle? A study of Gram negative bacterium *Escherichia coli*. Appl. Environ. Microbiol. 73:1712-1720.

[10] **Park H., Kim S. H., Kim H. J. and Choi S. (2006).**A New Composition of Nanosized Silica-Silver for Control of Various PlantDiseases.Plant Pathology Journal, 22(3): 295-302

[11] **Park HJ, Kim SH, Kim HJ, Choi SH (2006).** A new composition of nanosized silica-silver for control of various plant diseases. Plant Pathol. J. 22:25-34.

[12] **Perea-de-Lugue, A. and D. Rubiales, 2009**. Nanotechnology for parasitic plant control. Pest Management Science Journal, 65:540-545.

[13] **Prasad R, Swamy VS (2013).** Antibacterial activity of silver nanoparticles synthesized by bark extract of *Syzygium cumini*. J. Nanopart. http://dx.doi.org/10.1155/2013/431218.

[14] **Shah MA, Towkeer A (2010).** Principles of nanosciences and nanotechnology. Narosa Publishing House, New Delhi.

[15] **Sharma VK, Yngard RA, Lin Y (2009).** Silver nanoparticles: green synthesis and their antimicrobial activities. Adv. Colloid Interface Sci. 145:83-96.

[16] **Sharon M., Kr. Choudhary A. and Rohit K. (2010).** Review article nanotechnology in agricultural diseases and food safety. Journal of Phytology, 2(4): 83–92

[17] **Suman PR, Jain VK, Varma A (2010)** Role of nanomaterials in symbiotic fungus growth enhancement. Curr. Sci. 99:1189-1191.

[18] **The Organic and Non-GMO Report** , 2009.[webpage on the Internet] US organic standards board to ban nanotechnology from organic food. Fairfield, IA: The Organic and Non-GMO Report; 2009. [Accessed April 19, 2014]. Available from: http://www.non-gmoreport.com/articles/oct09/us_organic_standards_ban_nanotechnology.php#sthash.y2BGmFJB.dpuf.

[19] **The Organic and Non-GMO Report** 2010. [webpage on the Internet] Canada bans nanotechnology in organics.Fairfield, IA: The Organic and Non-GMO Report; 2010. [Accessed April 19, 2014]. Available from:http://www.non-gmoreport.com/articles/may10/canada_bans_nanotechnology_organics.php#sthash.a9TkE5CG.dpuf.

[20] **Torney F, Trewyn BG, Lin VS, Wang K (2007).** Mesoporous silica nanoparticles deliver DNA and chemicals into plants. Nat. Nanotechnol. 2:295-300.

[21] **Yamanka M, Hara K, Kudo J (2005).** Bactericidal actions of silver ions solution on *Escherichia coli* studying by energy filtering transmission electron microscopy and proteomic analysis. Appl. Environ. Microbiol. 71: 7589-7593.

[22] **Young KJ (2009)** Antifungal activity of silver ions and nanoparticles on phytopathogenic fungi. Plant Dis. 93(10):1037-1043.