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Nanotechnology in Agriculture

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Abstract

Agriculture is an area where new technologies are often applied to improve the yield of crops. Nano agriculture involves the employment of Nano particles in agriculture these particles will impart some beneficial effects to crops. The emergence of nanotechnology and the development of new Nanodevices and Nanomaterials open up potential novel applications in agriculture and biotechnology. Nanoparticles are materials that are small enough to fall within the nanometric range, with at least one of their dimensions being less than a few hundred nanometers. These materials would release pesticides or fertilizers at a specific time and targeted location. Nanoparticles tagged to agrochemicals or other substances could reduce the damage to other plant tissues and the amount of chemicals released into the environment.

Keywords: Nanoagriuclture; Nanoparticles; Nanodevices; Agro-chemicals; Pesticides

Abbreviations: OFR: Oxygen free Radical; VACNTs: Vertically-aligned multi-walled carbon Nanotubes; MSNs: Mesoporous silica Nanoparticles; CNTs: Carbon Nanotubes

Introduction

Nanotechnology is defined especially as growing and exciting technology at the scale of one-billionth of a meter sweeping away the barriers between the physics, chemistry and biology. Nanotechnology is the design, characterization, production and application of structures, devices and systems by controlling shape and size at nanometer scale [1].Nanotechnology in biomedical research has emerged as an interdisciplinary science that has quickly found its own niche in clinical methodologies including imaging, diagnostic, and therapeutics, drug delivery and tissue engineering [2].Nano medicine can design, build, manipulate, and optimize biological components at the Nano-scale level. This includes the applications of Nano materials and the fabrication of Nano devices to be used in Nano diagnostic, Nano drug delivery and drug discovery [3].

Understanding the disease mechanisms of complex biological systems is still a significant challenge. Biological systems consist of hundreds of thousands of genes and proteins which are very hard to identify and whose behavior is difficult to correlate, understand and predict. Synthetic biology, in combination to classical methods, is recently emerging as an alternative method [4]. Individual mechanisms operating at various stages of the disease like initial, intermediate and advanced need further study to propose appropriate therapeutic intervention [5].

Nano particles (NPs) use their optical scattering properties for imaging and diagnostics, and their photo thermal properties for various types of therapies. The situation was improved by using active molecular targeting with cell-specific molecules (peptides, antibodies) attached to NPs and coupling to cognate receptors at the membranes of specific target (diseased) cells [4].

Agriculture and the Environment

Agriculture is the largest interface between humans and the environment, and is a major cause of climate change and ecosystem degradation. In particular, fertilizer use leads to fundamental changes in the pools Fertilizer utilization to supplement soil nutrients, to promote plant growth and to increase crop productivity and food quality is prevalent in modern agriculture. As a result, crop production and global food security are highly dependent on fertilizers input to agricultural lands [6] .The selection and deployment of aims in stressed ecosystems therefore requires concerted research and technology development [7].

Pesticides use has dramatic consequences both in developed and developing countries [8].Sustainable agriculture aims at long term maintenance of natural resources and agricultural productivity with minimal adverse impact on the environment [9]. Pesticide chemicals may induce oxidative stress leading to generation of free radicals and alterations in antioxidants or Oxygen Free Radical (OFR) scavenging enzymes [10]. Synthetic or fumigant pesticides used for plant protection and pests controlling in stores usually bring about resistance in these pests [11].

Nanoparticles in Controlling the Plant Diseases

Today, application of agricultural fertilizers, pesticides, antibiotics, and nutrients is typically by spray or drench application to soil or plants, or through feed or injection systems to animals. Delivery of pesticides or medicines is either provided as "preventative" treatment, or is provided once the disease causing organism has multiplied and symptoms are evident in the plant [12].

In this context, nanotechnologies offer a great opportunity to develop new products against pests [13].

Nanotechnology improves their performance and acceptability by increasing effectiveness, safety, patient adherence, as well as ultimately reducing health care costs [14].

Nanoscale devices are envisioned that would have the capability to detect and treat an infection, nutrient deficiency, or other health problem, long before symptoms were evident at the macro-scale.

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This type of treatment could be targeted to the area affected with a greater awareness of the hazards associated with the use of synthetic organic insecticides, there has been an urgent need to explore suitable alternative products for pest control [12].The broad application of Molecular Biology revolutionized the field of Diagnostics [15].

Today, Nanomaterials have been designed for a variety of biomedical and biotechnological applications, including biosensors, enzyme encapsulation. Nanotechnology is based on the introduction of novel Nano-materials which can result in revolutionary new structures and devices using extremely biological sophisticated tools to precisely position molecule [16]. Nanoparticles technology has emerged as a strategy to tackle [17] developing new materials and selecting appropriate materials for each specific treatment, other factors need to be optimally selected in order to design better targeted Nano particles. These factors include the particles size, shape, sedimentation, drug encapsulation efficacy, desired drug release profiles, distribution in the body, circulation, and cost [18].

Development of targeted drug delivery will improve therapeutic efficacy through reductions in drug dosing intervals, and diminished toxicities [19] .The overall goal of this imaging Nanoparticles is to reduce the number of unnecessary problems in agriculture [20].

Nanoparticles mediated plant transformation has the potential for genetic modification of plants for further improvement. Specifically, application of Nanoparticles technology in plant pathology targets specific agricultural problems in plant–pathogen interactions and provide new ways for crop protection. Herein we reviewed the delivery of Nanoparticulate materials to plants and their ultimate effects which could provide some insights for the safe use of this novel technology for the improvement of crops [21].

Many of the preparation methods of Nanoparticles can be modified to create Nano structured films and Nano composites, although some types of nanostructures require completely novel approaches [22].

Carbon Nanotubes

Vertically-aligned multi-walled carbon Nanotubes (VACNTs) are arousing interest from researchers in biomedical area due to their exceptional combination of mechanical properties, chemical properties, and biocompatibility [23].Carbon Nanotubes (CNT) and functionalized fullerenes Bucky balls with bio-recognition properties provide tools at a scale, which offers a tremendous opportunity to study biochemical processes and to manipulate living cells at the single molecule level. Studies of this type can provide disease-gene-damage prone information for exploring DNA- safe therapeutics [24].

Carbon Nanotubes (CNTs) have become attractive electronic materials to date and their applications in future electric circuits and bio-sensing chips [25].CNT as vehicle to deliver desired molecules into the seeds during germination that can protect them from the diseases. Since it is growth promoting, it will not have any toxic or inhibiting or adverse effect on the plant.

Mesoporous Silica Nanoparticles

Nanoparticles can serve as 'magic bullets', containing herbicides, chemicals, or genes, which target particular plant parts to release their content.[26].Mesoporous silica Nanoparticles (MSNs) have attracted the attention of several scientists over the last decade due to their potential applications. Among the main features of mesoporous materials is the high surface area, pore volume and the highly ordered pore network which is very homogeneous in size [27].

Mesoporous silica Nanoparticles (MSNs) have been extensive investigated as a drug delivery system. It is well know that MSNs possess excellent properties such high specific area, high pore volume, tunable pore structures and physicochemical stability. In the beginning MSNs were used for controlled delivery of various hydrophilic or hydrophobic active agents. Later advances in the MSNs surface properties such as surface functionalization and PEG ylation rendered them as a promising drug delivery [28].

Mesoporous silica Nanoparticles (MSN) helps in delivering DNA and chemicals into isolated plant cells. MSNs are chemically coated and serve as containers for the genes delivered into the plants. The coating triggers the plant to take the particles through the cell walls. It was found that MPS/DNA complexes showed enhanced transfection efficiency through receptor-mediated endocytosis via mannose receptors. These results indicate that MPS can be employed in the future as a potential gene carrier to antigen presenting cells [29].

Nanosensors

Although biosensors have been around since glucose monitors were commercialized in the 1970s, the transition of laboratory research and innumerable research papers on biosensors into the world of commerce has lagged [30].

Application of Nanoscale materials for electrochemical biosensors has been grown exponentially due to high sensitivity and fast response time. In these applications, effective immobilization of biomolecules without altering bioactivity is the key in construction of stable and well-structured electrode materials for biosensor platform [31].

The developed biosensor system is an ideal tool for online monitoring of organophosphate pesticides and nerve agents. Bio-analytical Nanosensors are utilized to detect and quantify minute amounts of contaminants like viruses bacteria, toxins bio-hazardous substances etc. in agriculture and food systems. Most analysis of these toxins is still conducted using conventional methods; however, biosensor methods are currently being developed as screening tools for use in field analysis [32].

Nanoemulsion

The term 'Nanoemulsion' has been widely used to describe the complex systems consisting of oil phase, surfactant and water, which are optically isotropic and kinetically stable colloidal solution with droplet size in the range of 20-200 nm . Currently, Nanoemulsion are becoming the subject of many studies due to their wide range of particle sizes in Nanoscale, and this has contributed to more branches of potential uses and applications [33]. Nanoemulsion was characterized for particle size viscosity, surface morphology and refractive index [34].

Nanoparticles suspensions very often present a physicochemical instability during their storage. In order to overcome this lack of stability and facilitate the handling of these colloidal systems, the water elimination from the aqueous dispersions to obtain a dry solid form appears as the most promising strategy [35].

Nano-emulsions, as non-equilibrium systems, present characteristics and properties which depend not only on composition but also on the preparation method [36]. Nano-emulsions can encapsulate functional ingredients within their droplets, which can facilitate a reduction in chemical degradation

Silver Nanoparticles

Silver Nanoparticles are appearing with ever-increasing frequency in consumer products, with over 300 self-identified nanosilver containing products on markets. These include dispersions and powders marketed as antimicrobials As novel nanosilver is incorporated into an increasing number of products subject to FDA regulation, questions about formulation, pyrogenicity, sterility, and sterilization procedures are emerging [37] Since the size, shape and composition of silver Nanoparticles can have significant effect on their efficacy, extensive research has gone into synthesizing and characterizing silver Nanoparticles [38].

Silver Nanoparticles have also attracted much attention due to their diminutive size and novel material properties. With their nanometer scale size, which is responsible for different properties concerning the bulk material renders them suitable for applications. Therefore, many approaches have been used to prepare silver Nanoparticles for a rapidly growing list of catalysis, electronic, non-linear optics and biomaterial applications [39].

Nanosilver is used in agriculture to a wide extent because of its specific properties. A number of studies are conducted on the reaction of plants after their contact with nanosilver obtained by chemical reduction [40]. Nanomolecular silver solution reduced the incidence of root diseases. These examples demonstrate that the use of a colloidal nanosilver solution may considerably improve the growth and health of various plants.

Nanoparticles mediated nonviral gene delivery

Gene delivery systems are an important area in the field of genetic nanomedicine. Gene delivery involves the transport of genes, which requires a transport vehicle referred to as a vector. Possible vectors include viral "shells" or lipid spheres (Liposomes), which have properties that allow them to be incorporated into host cells [41].

Peptides and proteins have become the drugs of choice for the treatment of numerous diseases as a result of their incredible selectivity and their ability to provide effective and potent action [42].These studies suggest that research should be focused on designing a drug with an enhanced permeability and retention (EPR) effect [43].nanoconjugate is being developed for non-invasive detection of gene expression in cells [44].

Polymer based gene transfer: Non-viral gene medicines have emerged as a potentially safe and effective gene therapy method for the treatment of a wide variety of acquired and genetic diseases [45].

An important advantage of polymer-based gene delivery systems over viral transfection systems is that transient gene expression without the safety concerns can be achieved. In addition to the polymeric systems to deliver DNA, therapeutic ultrasound is potentially useful because ultrasound energy can be transmitted through the body without damaging tissues and could be applied on a restricted area where the desired DNA is to be expressed [46].

Liposome gene transfer: The liposome-based gene transfer strategy is one of the most studied Nonviral gene delivery strategies [47].A liposomal delivery system requires a complete understanding of the physicochemical characteristics of the drug–liposome system [48]. Many bacteria can control plant diseases by altering molecular processes leading to the production of pathogenicity and/or virulence factors by the pathogen [49].

Liposomes may offer several advantages as vectors for gene delivery into plant cells. Enhanced delivery of encapsulated DNA by membrane fusion, protection of nucleic acids from nuclease activity, targeting to specific cells, delivery into a variety of cell types besides protoplasts by entry through plasmodesmata [50] .In Liposome based gene therapy there is no toxicity potential in humans and plants [51].Our results should stimulate efforts to develop plant-based technologies for the removal of pollutants from contaminated environments[52]. Specific molecular changes have been suggested to be the reasons for the growth of gene therapies [53] a liposomal delivery system requires a complete understanding of the physicochemical characteristics of the drug–liposome system [54].

Biobeads gene transfer: Micrometer-sized calcium alginate beads referred to as "bio-beads" that encapsulate plasmid DNA molecules carrying a reporter gene. In order to evaluate the efficiency of the bio-beads in mediating genetic transfection, protoplasts isolated from cultured tobacco cells. Transfection was up to 0.22% efficient. These results indicate that bio-beads have a possibility for efficient transformation in plants [55]. Application of Nanoscale materials has been grown exponentially due to high sensitivity and fast response time [56]. Hence focus will be on those systems whose response time must be within few milliseconds to a few seconds [57].sometimes they may also cause some risk factors [58] .Drug delivery systems with Liposomes and Nanoparticles have become very popular in nanotechnology [59] sometimes these particles may also cause to microbial degradation [60].

A number of approaches are being developed to apply nanotechnology and particularly Nanoparticles to cleaning up soils contaminated with pesticides. To explore the benefits of applying nanotechnology to agriculture, the first stage is to work out the correct penetration and transport of the Nanoparticles into plants. This research is aimed to put forward a number of tools for the detection and analysis of core-shell magnetic Nanoparticles introduced into plants and to assess the use of such magnetic Nanoparticles in selected plant tissues.

Conclusion

A very interesting application of Nanoparticles in the scope of life sciences is their use as 'smart' delivery Systems. This research is aimed to put forward a number of tools for the detection of plant diseases and analysis of Nanoparticles introduced into plants and to assess the use of such Nanoparticles in selected plant tissues. The results open a wide range of possibilities for using Nanoparticles in general plant research and agronomy. Nanotechnology improves their performance and acceptability by increasing effectiveness, safety as well as ultimately reducing health care costs

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