NANOTECHNOLOGY: A NEW EMERGING AND FASCINATING FIELD OF SCIENCE FOR HUMAN WELFARE

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Abstract: In true world, it is desirable that the properties, behaviour, and types of nanomaterials should be improved to meet the aforementioned points. On the other hand, these limitations are opening new and great opportunities in this emerging field of research. To counter those limitations, a new era of ‘green synthesis’ approaches/methods is gaining great attention in current research and development on materials science and technology. Basically, green synthesis of materials/ nanomaterials, produced through regulation, control, clean up, and remediation process, will directly help uplift their environmental friendliness. Some basic principles of “green synthesis” can thus be explained by several components like prevention/minimization of waste, reduction of derivatives/pollution, and the use of safer (or non-toxic) solvent/auxiliaries as well as renewable feedstock. ‘Green synthesis’ are required to avoid the production of unwanted or harmful by-products through the build-up of reliable, sustainable, and eco-friendly synthesis procedures. The use of ideal solvent systems and natural resources (such as organic systems) is essential to achieve this goal. Green synthesis of metallic nanoparticles has been adopted to accommodate various biological materials (e.g., bacteria, fungi, algae, and plant extracts).

Key words: Nanotechnology, Nanomedicines, Agriculture science, Plant science.

Introduction: Although the term “*nanotechnology*” is very much in vogue, defining it is not simple. A nanometer(Greek, *nanos*, dwarf) is one billionth of a meter, or 1/75,000th the size of a human hair. An atom is about one third of a nanometer in width. Nanotechnology is not a well-defined field, butencompasses many technical and scientific fields such as medicine, chemistry, physics, engineering,biology, etc. One can view it as an umbrella term used to define the products, processes andproperties at the nano/micro scale. One of the major problems regulators andlawyers face regarding nanotechnology is the confusion and disagreement about its definition(Bawa 2007a-b; Bawa, 2011). There are numerous definitions of nanotechnology. One oftenused – yet sometimes troublesome – definition of nanotechnology was proposed by the US NationalNanotechnology Initiative (NNI) – a federal R&D program established by the U.S. government tocoordinate the efforts of government agencies involved in nanotechnology. It simply limitsnanotechnology to “*... about 1 to 100 nanometers ...*” (NNI, 2011). Various government agencies,including the Food and Drug Administration (FDA) and the Patent and Trademark Office (PTO)continue to use this vague definition based on a sub-100 nm size. Although the FDA is part ofthe NNI and had participated in the development of this narrow definition, it has yet to officiallyadopt the NNI’s definition for its own regulatory purposes, or establish a “*formal*” definition.The NNI nanotechnology definition presents numerous difficulties. For example, althoughthe sub-100 nm size range may be important to a nanophotonic company (e.g., a quantum dot’ssize dictates the colour of light emitted there from), this size limitation is not critical to a drug company from a formulation, delivery or efficacy perspective because the desired property (e.g.,improved bioavailability, reduced toxicity, lower dose, enhanced solubility, etc.) may be achievedin a size range greater than 100 nm. Moreover, this NNI definition excludes numerous devicesand materials of micrometer dimensions (or of dimensions less than 1 nanometer), a scale that isincluded within the definition of nanotechnology by many nanoscientists. Therefore, experts havecautioned against an overly rigid definition, such as this, based on a sub-100 nm size, emphasizinginstead the continuum of scale from the “*nano*” to “*micro*”.Add to this confusion the fact that nanotechnology is nothing new. For example, nanoscale carbon particles – “*high-tech soot nanoparticles*” – have been used as a reinforcing additive in tires for over a century. Another example is that of protein vaccines – they squarely fall within the definition of nanotechnology. In fact, many biomolecules are in the nanoscale. Peptides are similar in size to quantum dots and some viruses are in the size range of nanoparticles. Hence, most of molecular medicine and biotechnology can be classified as nanotechnology. Technically speaking, biologists have been studying all these nanoscale biomolecules long before the term "*nanotechnology*" became fashionable. Even though the National Institutes of Health (NIH) concurs that while much of biology is grounded in nanoscale phenomena, it has not reclassified most of its basic research portfolio as nanotechnology. In light of this confusion, the following definition of nanotechnology, unconstrained by anarbitrary size limitation, has been developed by Bawa *et al.* (2005): *The design, characterization, production, and application of structures, devices, and systems by controlled manipulation of size and shape at the nanometer scale (atomic, molecular, and macromolecular scale) that produces structures, devices, and systems with at least one novel/ superior characteristic or property.*Naturally, disagreements over the definition of nanotechnology carry over to the definitionof nanomedicine. At present, there is no uniform, internationally accepted definition for nanomedicine either. One definition, not constrained by size, yet correctly emphasizing that controlled manipulation at the nanoscale results in medical improvements and/or significant medical changes, comes from the European Science Foundation (EMRAC, 2004):*…the science and technology of diagnosing, treating and preventing disease and traumaticinjury, of relieving pain, and of preserving andimproving human health, using molecular tools and molecular knowledge of the human body.*Hence, the size limitation imposed in NNI's definition should be discounted, especially whendiscussing nanopharmaceuticals or nanomedicine. The phrase "*small technology*" may be moreappropriate in this context as it more accurately encompasses both nanotechnologies and microtechnologies. An internationally acceptable definition and nomenclature of nanotechnologyshould be promptly developed.

Nanotechnology, a new emerging and fascinating field of science, permits advancedresearch in many areas, and nanotechnological discoveries could open up novelapplications in the field of biotechnology and agriculture. In the field of electronics,energy, medicine, and life sciences, nanotechnology offers an expanding research,such as reproductive science and technology, conversion of agricultural and food wastes to energy and other useful byproducts through enzymatic nanobioprocessing,chemical sensors, cleaning of water, disease prevention, and treatment in plants usingvarious nanocides (Carmen et al. 2003; Nair et al. 2010). Although fertilizers arevery important for plant growth and development, most of the applied fertilizers arerendered unavailable to plants due to many factors, such as leaching, degradation byphotolysis, hydrolysis, and decomposition. Hence, it is necessary to minimize nutrientlosses in fertilization, and to increase the crop yield through the exploitation ofnew applications with the help of nanotechnology and nanomaterials. Nanofertilzersor nano-encapsulated nutrients might have properties that are effective to crops,released the nutrients on-demand, controlled release of chemicals fertilizers that regulateplant growth and enhanced target activity (DeRosa et al. 2010; Nair et al. 2010).Higher plants, as sessile organisms, have a remarkable ability to develop mechanismto perform better under suitable and unsuitable conditions. Nowadays scientists/researchers want to develop new techniques that could be suitable for plants to boosttheir native functions. Nanoparticles have unique physicochemical properties and thepotential to boost the plant metabolism (Giraldo et al. 2014). According to Galbraith(2007) and Torney et al. (2007) engineered nanoparticles are able to inter into plantscells and leaves, and also can transport DNA and chemicals into plant cells. Thisarea of research offers new possibilities in plant biotechnology to target specificgenes manipulation and expression in the specific cells of the plants. The researchershave augmented plants' ability to harvest more light energy by delivering carbonnanotubes into chloroplast, and also carbon nanotubes could serve as artificial antennaethat allow chloroplast to capture wavelengths of light which is not in their normalrange, such as ultraviolet, green, and near-infrared (Cossins 2014; Giraldo et al.2014). The engineered carbon nanotubes also boost seed germination, growth, anddevelopment of plants (Lahiani et al. 2013; Siddiqui and Al-Whaibi 2014). However,the majority of studies on NPs to date concern toxicity. Comparatively few studieshave been conducted on NPs are beneficiary to plants. Research in the field ofnanotechnology is required to discover the novel applications to target specific deliveryof chemicals, proteins, nucleotides for genetic transformation of crops (Torneyet al. 2007; Scrinis and Lyons 2007). Nanotechnology has large potential to providean opportunity for the researchers of plant science and other fields, to develop newtools for incorporation of nanoparticles into plants that could augment existing functionsand add new ones (Cossins 2014). In the present review, we discuss the recentdevelopments in plant science that focuses on the role of nanoparticles (NPs) in plantgrowth and development and also on plant mechanism.

Over the last decade, novel synthesis approaches/methods for nanomaterials (such as metal nanoparticles,quantum dots (QDs), carbon nanotubes (CNTs), graphene, and their composites) have been an interesting area in nanoscience and technology (Hoffmann MR et al., 1995, Huang X et al., 2006, O'Neal DP et al., 2016). To obtain nanomaterials of desired sizes, shape, and functionalities, two different fundamental principles of synthesis (i.e., top down and bottom up methods) have been investigated in the existing literature. In the former, nanomaterials/ nanoparticles are prepared through diverse range of synthesis approaches like lithographic techniques, ball milling, etching, and sputtering (Cao G. 2004). The use of a bottom up approach (in which nanoparticles are grown from simpler molecules) also includes many methods like chemical vapour deposition, sol–gel processes, spray pyrolysis, laser pyrolysis, and atomic/molecular condensation. Interestingly, the morphological parameters of nanoparticles (e.g., size and shape) can be modulated by varying the concentrations of chemicals and reaction conditions (e.g., temperature and pH). Nevertheless, if these synthesized nanomaterials are subject to the actual/ specific applications, then they can suffer from the following limitation or challenges: (i) stability in hostile environment, (ii) lack of understanding in fundamental mechanism and modelling factors, (iii) bioaccumulation/ toxicity features, (iv) expansive analysis requirements, (v) need for skilled operators, (vi) problem in devices assembling and structures, and (vii) recycle/reuse/regeneration.

In true world, it is desirable that the properties, behaviour, and types of nanomaterials should be improved to meet the aforementioned points. On the other hand, these limitations are opening new and great opportunities in this emerging field of research. To counter those limitations, a new era of 'green synthesis'approaches/methods is gaining great attention in current research and development on materials science and technology. Basically, green synthesis of materials/ nanomaterials, produced through regulation, control, clean up, and remediation process, will directly help uplift their environmental friendliness. Some basic principles of "green synthesis" can thus be explained by several components like prevention/minimization of waste, reduction of derivatives/pollution, and the use of safer (or non-toxic) solvent/auxiliaries as well as renewable feedstock. 'Green synthesis' are required to avoid the production of unwanted or harmful by-products through the build-up of reliable, sustainable and eco-friendly synthesis procedures. The use of ideal solvent systems and natural resources (such as organic systems) is essential to achieve this goal. Green synthesis of metallic nanoparticles has been adopted to accommodate various biological materials (e.g., bacteria, fungi, algae, and plant extracts). Among the available green methods of synthesis for metal/metal oxide nanoparticles, utilization of plant extracts is a rather simple and easy process to produce nanoparticles at large scale relative to bacteria and/or fungi mediated synthesis. These products are known collectively as biogenic nanoparticles. Green synthesis methodologies based on biological precursors depend on various reaction parameters such as solvent, temperature, pressure, and pH conditions (acidic, basic, or neutral). For the synthesis of metal/metal oxide nanoparticles, plant biodiversity has been broadly considered due to the availability of effective phytochemicals in various plant extracts, especially in leaves such as ketones, aldehydes, flavones, amides, terpenoids, carboxylic acids, phenols, and ascorbic acids. These components are capable of reducing metal salts into metal nanoparticles (Doble M, 2007). The basic features of such nanomaterials have been investigated for use in biomedical diagnostics, antimicrobials, catalysis, molecular sensing, optical imaging, and labelling of biological systems Aguilar Z. 2013. Here, we summarized the current state of research on the green synthesis of metal/metal oxide nanoparticles with their advantages over chemical synthesis methods. In addition, we also discussed the role of solvent systems (synthetic materials), various biological (natural extracts) components (like bacteria, algae, fungi, and plant extracts) with their advantages over other conventional components/solvents. The main aim of this literature study is to provide detailed mechanisms for green synthesis and their real world environmental remediation applications. Overall, our goal is to systematically describe "green" synthesis procedures and their related components that will benefit researchers involved in this emerging field while serving as a useful guide for readers with a general interest in this topic.

Effects of Nanoparticles on Plant Growthand Development: Nanoparticles interact with plants causing many morphological and physiologicalchanges, depending on the properties of NPs. Efficacy of NPs is determined by theirchemical composition, size, surface covering, reactivity, and most importantly the dose at which they are effective (Khodakovskaya et al. 2012). Researchers from their findingssuggested both positive and negative effects on plant growth and development,and the impact of engineered nanoparticles (ENPs) on plants depends on the composition,concentration, size, and physical and chemical properties of ENPs as well asplant species (Ma et al. 2010). Efficacy of NPs depends on their concentration andvaries from plants to plants. However, this review covers plausible role NPsin seed germination, roots, plant growth (shoot and root biomass) and photosynthesis.

Biological components for "green" synthesis: Innumerable physical and chemical synthesisapproaches require high radiation, highly toxic reductants,and stabilizing agents, which can cause perniciouseffects to both humans and marine life. In contrast,green synthesis of metallic nanoparticles is a one potor single step eco-friendly bio-reduction method thatrequires relatively low energy to initiate the reaction.This reduction method is also cost efficient (Dahoumane SA, 2016).For the ever-increasing population of the world, an increasing demand formore and more food is required. To cope with this alarming situation, there is a direneed for sustainable agricultural production. In agriculture, management of optimumplant nutrients for sustainable crop production is the priority-based area of research.

In this regard, much advancement in the area of plant nutrition has come forward andnano-nutrition is one the most interesting areas of research for sustainable agricultureproduction. Nanotechnology has revolutionized the world with tremendous advancementsin many fields of science like engineering, biotechnology,analytical chemistry,and agriculture. Nano-nutrition is the application of nanotechnology for the provisionof nano-sized nutrients for the crop production. Two sources of nanoparticles (NPs)have been used; biotic and abiotic. The abiotic form of nutrients or NPs is preparedfrom inorganic sources like salts but it is not safe because many of these are nonbiodegradable.While the biotic ones are prepared from organic sources which aredefinitely the biodegradable and environment friendly. So, a few studies/attempts havebeen made in the field of nano-nutrition and a lot more are expected in the near futurebecause this field of plant nutrition is sustainable and efficient one. Using nano-nutritionwe can increase the efficiency of micro- as well as macronutrients of the plants.

Overview of the Applications of Nanoparticlesin Agriculture: Applications of nanotechnology, in materials sciences and biomass conversiontechnologies applied in agriculture are the basis of providing food, feed,fiber, fire, and fuels. In the future, demand for food will increase tremendously,while the natural resources such as land, water, and soil fertility arelimited. The cost of production inputs like chemical fertilizers and pesticides isexpected to increase at an alarming rate due to limited reserves of fuel like naturalgas and petroleum (Prasad et al. 2012a). In order to overcome these constraints,the precisionfarming is a better option to reduce production costs andto maximize the output, i.e., agricultural production. Through the advancement in nanotechnology, a number of state-of-the art techniques are available forthe improvement of precision farming practices and will allow a precise controlat nanometer scale (De et al. 2014; Ngô and Van de Voorde 2014). The detaileddescription of the applications of nanotechnology in sustainable agricultural cropproduction is given in the following section of this chapter.

Effect of NPs on Seed Germination and Growthof Different Crop Plants: Nanomaterials (NMs) have great implications in sustainable agricultural cropproduction and many studies reported their positive impact on various crops. Mainly, germination of various crops has been reported to be improvedin these reports. For example, by the application of $nSiO_2$ in maize (*Zea mays* L.)and tomato (*Lycopersicum esculentum* Mill.) (Suriyaprabha et al. 2012a, b;Siddiqui and Al-Whaibi 2014), carbon nanotubes in tomato (*L. esculentum* M.),mustard (*Brassica juncea*), black gram (*Phaseolus mungo*) and rice (*Oryzasativa* L.) (Khodakovskaya et al. 2009; Nair et al. 2010; Ghodake et al. 2010),$nTiO_2$ in spinach (*Spinacia oleracea*) and wheat (*Triticul aestivum* L.) (Zhenget al. 2004; Hong et al. 2005; Yang et al. 2006; Lei et al.2008; Feizi et al. 2012; Larue et al. 2012), Al_2O_3 in *Arabidopsis thaliana* and*Lemna minor* L. (Lee et al. 2010; Juhel et al. 2011), Nano Si, Pd, Au, Cu inlettuce(*Lactuca sativa*) (Shah and Belozerova 2009), SiO_2 and TiO_2 in soybean(*Glycine max*) (Lu et al. 2001), the germination was improved. Moreover, bythe application of SiO_2–Ag, powdery mildew of pumpkin (*Cucurbita pepo*) wascontrolled(Park et al. 2006). An increase in the germination rate of the abovestated crops is an important aspect of the NMs however, the application of theseNMs as a nutrient source for the entire growth cycle of two crop plants needs to beexplored yet. So, the evaluation of these materials as a nutrient source, their criticalconcentration, and their phytotoxic effects, if any need, to be explored in future.

NANOBIOTECHNOLOGY APPLICATIONS

Medical Applications: Two of the most exciting and promising domains ofnanotechnology for advancements are health and medicine.Nanotechnology offers potential developments inpharmaceuticals, medical imaging and diagnosis, cancertreatment, implantable materials, tissue regeneration,and multifunctional platforms combining several of thesemodes of action.

Diagnosis: One primary goal in nanobiotechnology is the designof new methodologies to diagnose a number of diseasesat an early stage with cheaper material and moresophisticated equipment than is possible today. Muchresearch is currently being performed in this area. Theutilization of metal and semiconductor nanoparticles inbiomedical applications has been demonstrated by manyresearch groups.

The Au (gold) nanoparticles result in a dramatic increase in signalcontrast compared to other antibody-fluorescent dyetargeting agents.Nanobodies have the potential to be a new generationof antibody-based therapeutics and to be used in diagnosticsfor diseases such as cancer. The advantages ofnanobodies to developing therapeutics are the extremelystable and bind antigen with nanomolar affinity, a hightarget specificity and low toxicity, the ability to combinethe advantages of conventional antibodies with importantfeatures of small-molecule drugs, and their ability to beproduced cost effectively on a large scale. An option forthe use of antibodies in molecular biomedical is aptamers.These molecules are chemically stable and easily producesingle-stranded nucleic acid molecules. One example ofan application of aptamers in diagnosis is the work ofNiedzwiecki and colleagues. In this work, nanopores andaptamers were combined to detect a single molecule of thenucleocapsid protein 7 (NCp7), a protein biomarker of theHIV-1 virus, with high sensitivity. An interesting tool being developed today to be utilizedin tumour diagnosis is RNA nanoparticles. Althoughseveral researchers are adverse to RNA nanotechnology,due to the susceptibility of RNA to RNase degradationand serum instability, Shu and colleagues have developeda toolkit to obtain stable RNA nanoparticles.In this work, homogeneous RNA nanoparticles wereobtained, which targeted cancer exclusively *in vivo* withoutaccumulation in normal organs and tissues. Functionalizednanoparticle aggregating fluorescence imagingtechniques, known as quantum dots, have the potentialfor real-time and non-invasive visualization of biologicalevents *in vivo*. The nanoparticles can provide a solidsupport for sensing assays with several kinds of ligandmolecules attached to each nanoparticle, simplifying assaydesign. They can also withstand significantly larger numberof cycles of excitation and light emissions than typicalorganic molecules, which more readily decompose,increasing the labeling ratio for higher sensitivity in complexbiological systems. Another advantage is that theseminiaturized fluorescent nanoparticles can also be easilytaken up by cells through endocytosis and subsequentlyused for site-specific intracellular measurementsand long-term tracking of biomolecules in real time.This tool is being studied by several groups around theworld.

Gene Therapy: Gene therapy is a recently introduced method for thetreatment or prevention of genetic disorders by correctingdefective genes responsible for disease developmentbased on the delivery of repaired genes or the replacementof incorrect ones. The most common approachfor correcting faulty genes is insertion of a normal gene into a nonspecific location within the genome to replacea nonfunctional gene. An abnormal gene could also beswapped for a normal gene through selective reverse mutation,which returns the gene to its normal function.25Mammalian cells typically have a diameter of a fewmicrons and their organelles are within the nanometerrange. The use of nanodevices has the advantage of enteringthe cells more easily when compared to larger devicesand they can, therefore, interact better with the cells or atleast in a different way.26The use of nanotechnology in gene therapy couldbe applied to replace the currently used viral vectorswith potentially less immunogenic nanosize gene carriers.Delivery, therefore, of repaired genes or the replacementof incorrect genes are fields in which nanoscale objectscould be introduced successfully.1 The use of nanotechnology,here exemplified as the use of nanoparticles, hassome advantages in gene delivery: the structure of thenanoparticles protects the nucleic acids from degradationby nucleases and the environment; it also minimizes sideeffects by directing the nucleic acid to the specific locationof action; they facilitate cell entry of nucleic acids and normally nanoparticles sustain gene delivery for longerperiods when compared to other vehicles.

Drug Delivery: Controlled delivery systems are used to improve the therapeuticefficacy and safety of drugs by delivering themto the site of action at a rate dictated by the need of thephysiological environment, which in turn would reduceboth toxicity and side effects. Electrospun nanofibersmay serve as a promising delivery vehicle as a result oftheir 3D nano-sized features that closely resemble those ofthe ECM. By this technique it is possible to incorporatebiological molecules by using an emulsion or directly in apolymer solution.Co-axial also is used in drug delivery due its capacityof producing micro/nanotubes, drug or protein-embeddednanofibers, and hybrid core–shell nanofibrous materials.Structures built by electrospinning or co-axial permit theliberation of growth factors as epidermal growth factor(EGF), fibroblast growth factor (FGF), transforminggrowth factor (TGF), bone morphogenetic protein (BMP),and neurotrophins and neurokines, among others, used forneural, endothelial, and bone formation, etc.Another nanotechnology tool which is under intenseinvestigation for drug delivery is nanoparticles. They canprincipally be fabricated by lipids and polymers.Polymeric compounds that are currently being used in drugproducts include poly(DL-lactic-coglycolic acid) (PLGA)polyvinyl alcohol, poly(ethylene-co-vinyl acetate), polyimide,and poly(methylmethacrylate).26 Co-delivery isan alternative for the administration of different drugs,which by conventional therapeutic method cannot be usedtogether. Therefore, nanoscale systems can be used tofacilitate the delivery of incompatible drugs. They can alsobe used in theranostics, in which the particle is used as adevice to diagnose and treat the disease at the same time.These techniques are also used for the liberation of pharmacologicalagents against several diseases, such as bacterialinfection, inflammations, and principally cancer,among others. They are also being investigated as a toolfor the delivery of drugs through the blood-brain barrier.

Tissue Engineering: The goal of TE on a nanoscale is to createbiomaterials that direct interactions between cells and theirmicro-environment, by the creation of nanoscale molecularsignals of biological interest. Thereby, the cells receive,process, and respond to information presented in the surroundingenvironment, these actions being essential for thecontrol of cell behavior.43From the techniques used to construct biomaterials tobe cultivated with cells, electrospinning is the most widelystudied and it has also been demonstrated to give the mostpromising results in terms of TE applications. It is a highlyversatile method of transforming solutions, mainly madefrom polymers, in continuous filaments with diametersranging from a few micrometers to nanometers. Throughthis method, the fibers can be obtained randomly or inan ordered way. Electrospinning works by the electrostaticprinciple, where the solution is supplied to the system viaa syringe and is subjected to a difference in electrical voltage,yielding solid fiber at the end of the process.44 Coaxialelectrospinning is a modification or extension of theelectrospinning technique. Using this compound spinneretmethod, two components can be fed through different coaxialcapillary channels and are integrated into a core–shellstructured composite fiber. The nanofibers obtained byboth methods have been used in many biological applications,as follows. The skin is an organ that serves as aphysical barrier to the external environment and consistsprimarily of epidermis and dermis. Because the skinacts as a protective barrier, any injury caused to it shouldbe repaired quickly and efficiently.Especially in large burns and chronic wounds, the treatmentsavailable are insufficient to prevent scar formationand promote healing of the patient. Thus, the regenerationof skin is an important field for TE. The substitutesfabricated for use in TE normally act as supplementary dermaltemplates and improve wound healing. Several studiesare being conducted in an attempt to create an idealsubstitute that could eliminate the limitations encounteredso far in the current skin substitutes.

Pathogen Detection: There have been recent outbreaks of food disease, mostnotably the outbreak of *Escherichia coli* in Germany inwhich a total of 3,602 cases were reported and 47 peopledied. Clearly there is a need to monitor food-bornepathogens throughout the food chain from production, processing,and distribution to the point-of-sale. Pathogensmay be present in low numbers in a sample for analysis,making detection difficult. Traditional detection methodsfor pathogen determination like colony count estimationcan be laborious and time consuming with completionranging from 24 h for *E. coli* to 7 days for *Listeria monocytogenes*,and these pose significant difficulties for qualitycontrol of semi-perishable foods. Pathogen numberscan also be underestimated using these methods due tomicroorganisms entering viable but non-culturable statesdue to environmental stress. Upon resuscitation from thisstate by, for example, an increase in temperature of thecells, microorganisms can regain the ability to cause infection,thus posing a health risk.

Advances in the manipulation of these nanomaterialspermit binding of different biomolecules such as bacteria,toxins, proteins, and nucleic acids.76 One of the majoradvantages of using nanomaterials for biosensing is thatbecause of their large surface area, a greater number ofbiomolecules are allowed to be immobilized and this consequentlyincreases the number of reaction sites availablefor interaction with a target species. This property, coupledwith excellent electronic and optical properties, facilitatethe use of nanomaterials in label-free detection and inthe development of biosensors with enhanced sensitivitiesand improved response times. Biosensors are currentlyused in the areas of target identification, validation, assaydevelopment, lead optimization and absorption, distribution,metabolism, excretion, and toxicity. They are bestsuited to applications using soluble molecules and overcomemany of the limitations that arise with cell-basedassays. Biosensors are particular useful in the study ofreceptors because they do not require the receptor to beremoved from the lipid membrane of the cell, which canbe necessary with other assay methods.Single-walled carbon nanotubes have been used as aplatform for investigating surface–protein and protein–protein binding, as well as to develop highly specificelectronic biomolecule detectors. Non-specific binding onnanotubes, a phenomenon found with a wide range of proteins,is overcome by the immobilization of polyethyleneoxidechains. A general method is followed that entails theselective recognition and binding of target proteins, conjugatingtheir specific receptors to polyethylene-oxide functionalizednanotubes. These arrays are attractive becauseno labeling is required, and the entire assay can be donein the solution phase. This combined with the sensitivityof nanotube electronic devices, provides highly specificelectronic sensors for detecting clinically importantbiomolecules, such as antibodies associated with humanautoimmune diseases.

Food Safety: The research in the area of nanobiotechnology in foodinvolves mainly adding antioxidants, antimicrobial, biosensors,and other nanomaterials at packaging. The medical,pharmaceutical, and cosmetics industries have been usingnanoparticles made from food to improve the characteristicsof its products. Nanobiotechnology in food packaginghas been a focus in recent years. The potentialperspectives of bio-nanocomposites for food packagingapplications together with bio-based materials, such as edibleand biodegradable nanocomposite films have gainedattention. Among the available metal nanoparticles, silverand related materials have been utilized in many nanobasedcommercial products for their antimicrobial property.Studies suggest that the antimicrobial performance isenhanced due to an intensive surface area/reduced particlesize.The use of nanomaterials as antimicrobial agents hasreceived increased attention in recent years. Since theantimicrobial properties of silver are well documented itis no surprise that the antimicrobial activity of AgNPsdominate publications in this area. Others nanoparticlesas zinc and sulfur, showed antimicrobial activityaccording to some authors. The combination of silvernanoparticles with water soluble biopolymers will producenew antimicrobials. Based on this, various natural polymerssuch as gum acacia, starch, gelatin, sodium alginate,and carboxy methyl cellulose have been employed toprepare biocompatible polymeric silver nanocomposites.Chitosan, a natural polymer composed of poly(-(1-4)-2-amino-2-deoxy-D-glucose), is one of the structuralpolysaccharides that is abundantly available in nature aftercellulose. Chitosan interacts very easily with bacteriumand binds to DNA, glycosaminoglycans, and most of theproteins, thereby enhancing the antimicrobial effect ofsilver nanoparticles.The authors studied the incorporation of curcumin intochitosan-PVA nanoparticles film to improve significantlythe therapeutic antibacterial efficacy of the film. The developedsilver nanocomposite films have exhibited fairly goodmechanical strength and superior antimicrobial properties.

Further, the work demonstrates a promising methodto combine silver nanocomposites with a natural compound(curcumin) in developing novel antimicrobial agents. Theseagents may find potential applications in antimicrobialpackaging materials and wound dressing/wound burns.Vivekanandhan impregnated AgNPs into microcrystallinecellulose using Murraya koenigii extract as thereducing agent at ambient conditions and extending theirapplication into the fabrication of polylactic acid (PLA)based antimicrobial bionanocomposite films. Costa evaluated the effects of silver-montmorillonite nanoparticles(Ag-MMT) on microbial and sensorial quality decayduring storage of a packaged fresh fruit salad. The authorsobserved that the shelf life increased about 5 days whenusing the sample with 20 mg of Ag-MMT. To sum up, itcan be concluded that Ag-MMT nanoparticles optimizedin a proper packaging system could represent a solution tocontrol the quality decay of fresh-cut fruit.

Sastry identified areas of nanoresearch determinantsof food security, which are productivity, soil health,water security and storage, and distribution of food. For thedistribution of food, the thematic areas are food processingand food packaging. For these, the nanoresearch areasare nanoscale phenomena, nanoparticles, biosensors, nanofibers,among others. Some applications for these areas arenatural biopolymer-based nanocomposite films used forfood packaging for safe storage, nanowire immunosensorsarray for the detection of microbial pathogens, quick detectionof food-borne pathogens using bioconjugated nanomaterials,biosensor, nanocantilevers and carbon nanotubes,and nanoscale titanium dioxide particles as a blockingagent of UV light in plastic packaging. Gonçalves et al.88used curcumin that is extracted from the rhizomes of the*Curcuma* species and is a natural polyphenol with antioxidative,anti-inflammatory, and anti-cancer properties toproduce a nanogel. The authors reached a dextrin nanogelthat served as an effective “nanocarrier” for the formulationof lipophilic curcumin by increasing its water solubility,improving its stability, and controlling its releaseprofile. The small size of this system can be advantageousfor passive targeting of tumor tissues. Butnariu andGiuchici,studied the therapeutic effects of nanoemulsionsmade of an aqueous extract of propolis and lycopene.The results showed that inflammation decreased up to100% using nanoemulsions and a lycopene antioxidant asa nanoemulsion component. In addition, its moisturizercharacteristic improves the ability of the skin to defendagainst sunlight.

Nanomaterials usage in Plant Science: Nanomaterials have many usages in all stages of agriculturalproduction, in different forms and various procedures such as:

1. Nano-fertilizer for balance plant nutrition
2. Plant protection ingredients (pesticides, fungicides, weedicides)
3. Weed management.
4. Nano pesticides
6. Nano sensors
6. Post-Harvest Technology
7. Bioprocessing (bio synthesized) nanoparticles for agriculturaluse
8. Bio sensors for Aqua culture
9. Nano biotechnology (Analysis of gene expression and Regulation)
10. Monitoring the identity and quality of agricultural produce
11. Seed technology.
12. Water management.
13. Plant growth regulators.
14. Soil management.
15. Agricultural engineering aspects.
16. Food technology.

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