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Application of Nano-materials and Nano-Technology in Agriculture

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Abstract—*Nanotechnology has been in tremendous use in last two decades including in the field of medicine, communication, aerospace, environment, household goods and scientific researches. Nanotechnology has proved its place in agricultural sciences and related industries, as an interdisciplinary technology and a pioneer in solving problems and filling the loopholes. Nanotechnology has many applications in all stages of production, processing, storing, packaging and transport of agricultural and horticultural products. A very interesting application of nanoparticles in the scope of life sciences is their use as 'smart' delivery systems. Nanoclay nanomaterial has been in demand for its recycling nature. Given the high surface area relative to the amount of nanomaterials, fertilizers based on nanotechnology have the potential to surpass conventional fertilizers. Enzymes based nano sensors can act as a sensing element as they are very specific in attachment to certain biomolecules. Nanosized TiO_2 in low concentration (2 to 10 ppm) could encourage seed germination of different crops. In packaging, the nano particles can perform wide variety of applications, such as: polymer/clay nanocomposites as high barrier packaging materials, silver nanoparticles as potent antimicrobial agents, and nanosensors and nanomaterial-based assays for the detection of food-relevant analytes.*

Keywords*: nanomaterials, crops, seed germination, smart delivery*

1. INTRODUCTION

Nano science is the study of and applications for nano materials in variation domains of science and technology. The scope of nano science includes the study of atoms, molecules and atom crystals in the size range of 1-100 nm. A nanometer is one billionth of a meter. Overall nano refers to a size scale between 1 nanometer (nm) and 100 nm. For comparison, the wavelength of visible light is between 400 nm and 700 nm. A leukocyte has the size of 10000 nm, a bacteria 1000-10000 nm, virus 75-100 nm, protein 5-50 nm, deoxyribonucleic acid (DNA) ~2 nm (width), and an atom ~0.1 nm In this scale, physical, biological and chemical characteristics of materials have fundamentally different from each other and often unexpected actions are seen from them. Nanotechnology considers the topics with viruses and other pathogens scale. So has high potential for identify and eliminate pathogens.

Researchers are working on pesticides encapsulated in nanoparticles; these only release pesticide in an insect's stomach, which minimizes the contamination of plants themselves (Chen and Yada, 2011).

Another development being looked at is a network of nanosensors and dispensers throughout a food crop. The sensors recognize when a plant needs nutrients or water, before you could see any sign that the plant is deficient. The dispensers then release fertilizer, nutrients, or water as needed, optimizing the growth of each plant in the field one by one.

2. AGRICULTURE APPLICATION

The research of nano technology in agriculture has been under taken for quite some time. However the success rate is still very low. There are a few examples of standalone researches and implementation of nano- technology in agriculture. The technology in agriculture can be summarized as in Fig. 1.

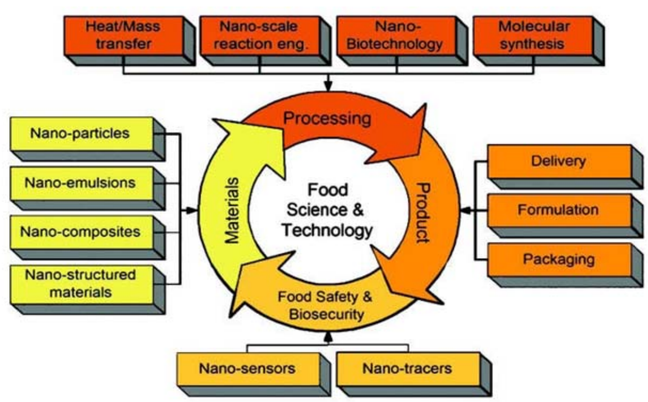


Fig. 1: Nano Science and technology in agriculture

-Membrane made from organic waste such as seaweed, fishbone, fertilizer etc. can prevent water loss from soil and plant root in arid and desert region. It can reduce the irrigation requirement by 30-50%. Also can increase or decrease the sun light reflection by adding necessary pigments.

-Using NT, the strength of biodegradable polylactic acid (PLA) fibers made from corn and potato can be doubled, which is used for covering the crop from rain and pest. They added some organic filler material to the double the strength of the organic fibers.

- Similar to human disease prevention techniques with NT, the crop disease control has been attempted for crops like soybean etc. Researchers also attempted to diagnose and cure the plant and animal diseases on the spot using nanotube devices. Naturally occurring clay nanotubes can be used for specific pesticide delivery. Measuring differential protein production in both healthy and diseased states leads to the identification of the development of several proteins during the infection cycle. These nano-based diagnostic kits not only increase the speed of detection but also increase the power of the detection (Prasanna, 2007).

- Nanoscale transistors can improve the performance of the agricultural machineries. Miniature sensors can be used to identify food spoilage and help in grading high nutritious grain materials. Tata Chemicals, India is developing nanotechnology-based crop-specific, high-value fertilizers to improve agricultural yields. So, less fertilizer required to get better crop yield (Mousavi and Rezaei, 2011).

The application of nano-meterials in agricultural crops is increasing day-by-day (Fig. 2).

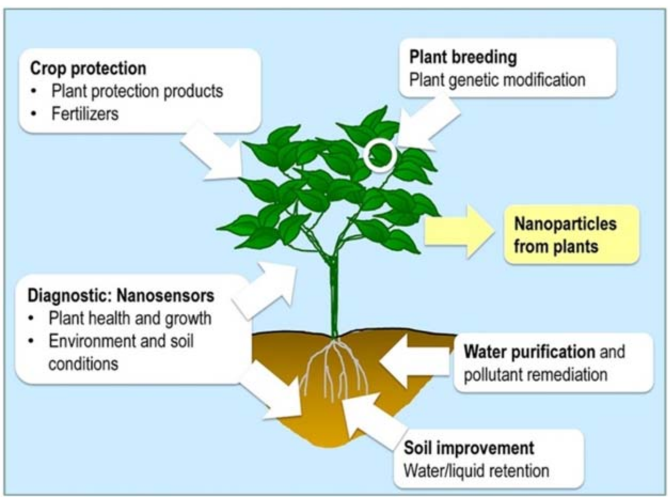


Fig. 2: Possible application of Nano materials (Parisi et al., 2015)

Seed germination

Silver nano-particles were used for germination test of Boswellia ovalifoliolata. Higher percentage (95%) of seed germination found in treated seeds when compare to control. The control seeds (water) took longer time (10 to 20 days) to sprout, whereas all treated seeds sprouted within 10 days (Savithramma et al., 2012).

3. FOOD PROCESSING

The nanotexturing of foodstuffs has been claimed to give new tastes, improved textures, consistency and stability of emulsions, compared with equivalent conventionally processed products. Mayonnaise, which is an oil in water emulsion that contains nanodroplets of water inside the oil droplets. The mayonnaise may offer taste and texture attributes similar to the full-fat equivalent, but with a substantial reduction in fat intake by the consumer.

Another area of application involves the use of nanosized or nano-encapsulated food additives. Nano- encapsulated additives can assists in terms of preserving the ingredients and additives during processing and storage, masking unpleasant tastes and flavours, controlling the release of additives, better dispersion of water-insoluble food ingredients and additives, as well as improved uptake of the encapsulated nutrients and supplements

Food packaging is the major area of application of metal (oxide) ENMs. Example applications include plastic polymers with nanoclay as a gas barrier, nanosilver and nanozinc oxide for antimicrobial action, nanotitanium dioxide for ultraviolet (UV) protection, nanotitanium nitride for mechanical strength and as a processing aid, nanosilica for surface coating (Joseph and Morrison, 2006).

The nanoclay mineral is mainly montmorillonite (also termed as bentonite), which is a natural clay obtained from volcanic ash/rocks. Nanoclay has a natural nano-scaled layer structure and is organically modified to bind to polymer matrices. Coatings containing nanoparticles: Coatings that contain nanoparticles are used to create antimicrobial, scratch resistant, anti-reflective, or corrosion-resistant surfaces (Fey et al., 2005). This involves the coating of nanoparticulate form of a metal, metal oxide or a film resin substance with nanoparticles. Examples of FCMs with nanocoating include antibacterial kitchenware, cutting boards and teapots. The nano-coatings are produced for fruit that covering the fruits completely, and prevent of fruit weight loss and shrinkage. (Predicala, 2009)

Nanotechnology has also enabled the development of nanosensors that can be applied as labels or coatings to add an intelligent function to food packaging in terms of ensuring the integrity of the package through detection of leaks. Porous hollow silica nanoparticles, developed for the controlled delivery of the water-soluble pesticide validamycin with a high loading capacity (36 wt%), have been shown to have a multi-staged release pattern.

They produced microscopic probes or nano barcodes that could tag multiple pathogens in a farm which can easily be detected using any fluorescent-based equipment (Prasanna, 2007). This on-going project generally aims to develop a portable on-site detector which can be used by nontrained individuals (Li et al., 2013)

Biosensor is composed of a biological component, such as a cell, enzyme or antibody, linked to a tiny transducer, a device powered by one system that then supplies power (usually in another form) to a second system. The biosensors detect changes in cells and molecules that are then used to measure and identify the test substance, even if there is a very low concentration of the tested material. When the substance binds with the biological component, the transducer produces a signal proportional to the quantity of the substance (Johnson, 2005). With the use of nano sensors will be determined every small part of farm how much needs to fertilizer and chemical pesticides. Therefore, use of inputs will be optimal and safe products and economic efficiency is increased.

Food contamination from environment

The main products and materials identified include cosmetics and personal care products (TiO_2, ZnO, fullerene (C_{60}), Fe_2O_3, Ag, Cu, Au), catalysts, lubricants and fuel additives (CeO_2, Pt, MoS_3), aints and coatings (TiO_2, SiO_2, Ag, quantum dots), water treatment and environmental remediation (Fe, e–Pd, polyurethane), agrochemicals (porous SiO_2 carriers and other nanosized agrochemicals), food packaging (Ag, nanoclay,TiO_2, ZnO, TiN), nanomedicine and carriers (silver, Fe, magnetic ENMs).

Water filtration

The use of nano particles and nano-filtration provides possibility of refining and improving water with speedy and accuracy. The fabric can be wiped across a surface and tested to determine whether the pathogens are present, perhaps indicating their presence by a change in colour (Yacubowicz and Yacubowicz, 2007).

4. RENEWABLE ENERGY SOURCES

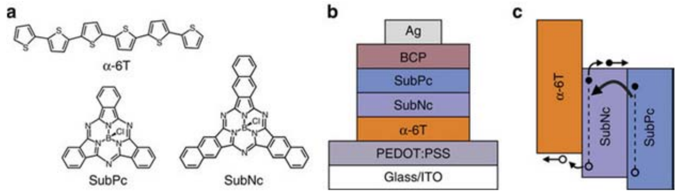
Solar energy is perhaps the most abundant and attractive long-term renewable energy source. However, new technology breakthroughs are needed to make solar energy conversion more cost-effective and more readily deployable on large scales. In the past decade, low-cost, nanostructured organic solar cells made from polymers like plastics have emerged as one possibility. Advances in nanotechnology will lead to higher efficiencies and lower costs, and these can and likely will be significant in solar energy sector. In fact, nanotechnology is already having dramatic effects on the science of solar cells (DeRosa *et al*., 2010).

Photovoltaic cells

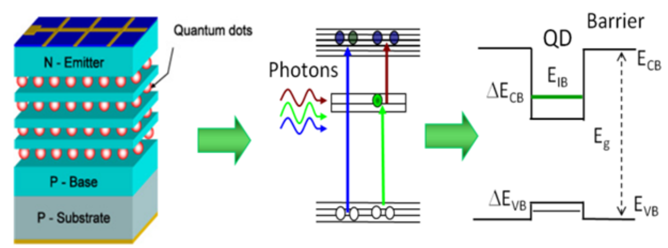
Photovoltaic cells can be mainly divided into two groups. Such as i) Single crystalline structure, ii) Dy sensitized structure (Fig. 3)

Single crystalline structure

  - o Wide spread, Expensive to manufacture, Low efficiency
- Dye sensitized (Nano crystals)
  - o Inexpensive to manufacture, Flexible
- Si (Silicon) nano crystal with different bandgap to acquired full solar spectrum
- Quantum confined nano crystals to generate multi exciton generation
- Organic dye sensitized solar cell
- Charge carrier recombination can be replaced with nano particles and nano structures
- Carrier collection efficiency can be improved using nano wires or nano tubes



(a)



(b)

Fig. 3: Solar cell (a) Organic solar cell; (b) Quantum dot solar cell

5. WAY FORWARD

Nanotechnology has many applications in the field of agricultural machinery such as: application in machines structure and agriculture tools to increase their resistance against wear and corrosion and ultraviolet rays; producing strong mechanical components with use of nano-coating and use of bio-sensors in smart machines for mechanical-chemical weed control; production nano- cover forbearings to reduce friction. Nano fertilizers will be absorbed by plants rapidly and completely. Nano encapsulated slow release fertilizers have also become a trend to save fertilizer consumption and to minimize environmental pollution. Super water adsorbents made by nanotechnology, has an important role in storage and protecting water in arid and semiarid regions.

The nanotechnology is used in production of alternative fuels and reduction environmental pollution. The advance solar cell and fuel cell will be the future of renewable energy. The renewable energy sources will be used in agricultural applications.

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