NANO TECHNOLOGY RELATED TO ITS IMPACT ON SEED AND AGRICULTURE

Abstract

The global agricultural landscape faces unprecedented challenges due to climate change, resource depletion, and biodiversity loss, necessitating a transformative approach to ensure food security. Traditional farming practices have proven inadequate in addressing the intricacy of these challenges since they are complex, time-consuming, and labour-intensive in nature. Furthermore, the effectiveness of traditional farming is decreased by inefficiencies and a huge demand for crop nutrients. This promotes the extensive use of agrochemicals, which pose a serious environmental risk. As a result, scientists are actively researching new techniques to successfully address these persistent difficulties. Nanotechnology has emerged as a transformative force in the fields of seed science and agriculture, offering innovative solutions to address the challenges of global food security and sustainable agriculture. Through a comprehensive review of the literature, this chapter deals with the diverse strategies harnessed by nanotechnology to elevate seed quality and strengthen the sustainability of agricultural processes.

Keywords: Seed science, Nanotechnology, Climate change , Nanosensors, Nanoparticles

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I. INTRODUCTION

Nanotechnology works with materials with a metre-scale in billionths in size because the term "nano" implies "one billionth." By genetically modifying plants, delivering genes and medication molecules to precise cellular locations, and using nano-array-based gene technologies to monitor how genes are expressed in stressed plants and animals, using nanotechnology may boost agricultural productivity. The potential is growing as efficient techniques and sensors are developed for precision agriculture, early disease and contaminant resource management, detection in food products, smart delivery systems for agrochemicals like fertilizers and pesticides, smart systems integration for food processing, packaging, and other areas like monitoring agricultural and food system security. Long-term economic growth in this sector is predicted to be primarily driven by advances in nanotechnology, which will also benefit ecosystems, farmers, consumers, producers, and society as a whole.

At this time, nanotechnology—a young, exciting subject of science—is useful in many fields. It has significant advantages for both agriculture and the field of biotechnology. Nanotechnology refers to the practise and study of manipulating matter at the nanoscale. Nanotechnology focuses on the manipulation of materials that have a minimum of one dimension and have sizes ranging from 1 to 100 nanometers. A billionth of a metre, or 10-9 m, is referred to as a nanometre (nm). Without the use of agrochemicals like fertilizers, pesticides, etc., modern agriculture cannot produce food sustainably or efficiently. However, each agrochemical has some possible negatives, such as the potential to leave residues or contaminate water sources on food products that are hazardous to environmental and human health (Kah, 2015). Therefore, proper management and control of inputs may be able to lower these risks. In order to feed the expanding population, Global population growth is increasing..Use of contemporary or innovative methods that can boost production and improve quality in agriculture is required. The establishment of an alternative method utilizing artificially intelligent nanotools could be a great way to revolutionize the agricultural system, reduce the environmental impact of current agriculture, and increase both the quality and quantity of yields. (Sekhon, 2014; Liu and Lal, 2015). The rapidly developing science of nanotechnology has enormous promise to modernize agriculture and related industries. Without a question, new and cutting-edge technologies like nanotechnology are essential to the sustainable expansion of the agricultural industry. Nanotechnology in agriculture is currently concentrated on target farming, which uses special nanoparticles to increase the productivity of crops and livestock. Nanotechnology has the ability to improve seed quality, plant protection, food quality, animal and plant disease detection, plant growth monitoring, and global food production.

Nanotechnology's primary goal is to increase the efficacy and sustainability of agricultural practices by requiring less input and producing less waste than conventional goods and methods. The use of nanotechnology in agriculture holds enormous potential due to its high reactivity, improved bioavailability, bioactivity, and surface impacts of nanoparticles. The need for environmentally sound, environmentally compatible crop production methods that can boost agricultural output and ensure global food security is growing. Application of nanoparticles or nanomaterial is a viable substitute for conventional farming methods, which have badly harmed the agro-ecosystem, in order to achieve this goal. There are a number of approaches used to boost seed quality, each of which has advantages of its own. As a result of physiological changes during seed storage, such as delayed germination and decreased tolerance to unfavorable storage conditions, germination decreases, which in turn results in slower seedling growth. According to Murthy *et al.* (2003), the main biochemical changes seen during storage include lipid peroxidation caused by free radicals, enzyme deactivation, cell membrane disintegration, and genetic damage. According to numerous studies, soybean seedling vigour and germination were improved by mid-term hydration-dehydration treatments after storage (Mandal *et al.*, 2000). By implementing new alternative technologies, it can be limited to some extent. Nanotechnological techniques might be a viable option for enhancing the quality and deteriorating process of seeds. The objective of the current review is to summarize and evaluate the potential of nanotechnology as a different strategy for enhancing seed quality through nanoparticles.

Nanoparticles have better qualities than bulk materials:

Why Nano is Important?

- Nanoparticles have better qualities than bulk materials
- Nanoparticles can be layered on surfaces, resulting in increased activity due to the large surface area.
- Materials' strength or electrical properties, increasing their reactivity to chemicals
- The physical, biological and chemical properties of a material are distinct from its molecules or bulk matter at the nanoscale.
- The permeability of nanoparticles across biological membranes is increased.
- Nanoparticles have antibacterial properties and respond differently to different species.
- By making electrostatic contact with the membrane, endangering the integrity of the membrane.

II. NANOPARTICLES

Materials with at least two dimensions are known as nanoparticles (NPs). and a size between 1 and 100 nm (Ball, 2002). Now, the question of "Why 100 nm and not 150 nm?" or "Why not 1 to 1000 nm?" is pertinent. This is due to the definition's emphasis on the effect that a dimension has on a particular substance. The appearance of quantum events should be taken into account rather than trying to pin down the exact dimension at which this impact emerges. Nanoscience examines how small-scale materials exhibit size-dependent quantum phenomena in addition to tiny particles, which are fundamentally dinstinct from the characteristics of bulk materials. The exceptional characteristics of nanoparticles, which are not present in bulk materials, include surface area, cation exchange capacity, ion adsorption, and complexation. According to Maurice and Hochella (2008), a nanoparticle varies from bulk material in that a large number of its atoms are located on the surface. There may be surface compositional differences between macroparticles and nanoparticles, site kinds, densities, and reactivity to adsorption and redox reactions, among other chemical processes (Waychunas *et al.*, 2005; Hochella *et al.*, 2008). These variations could be utilized to develop nanomaterials that improve seed quality.

III. ENHANCING SEED QUALITY USING NANOTECHNOLOGY

In addition to easily measurable traits like viability, seed lot purity, vigour, health and mechanical damage, a more enigmatic feature, is also a crucial aspect of seed quality (Perry, 1980). Because seeds contain the entire crop's genetic makeup, they serve as the delivery vehicle for agricultural biotechnology and crop enhancement. Companies need high-quality seeds in order to protect their investment in crop enhancement and ensure that these advantages are not lost when the seeds are sown in the field. Numerous studies have shown how particular nanoparticles can improve the quality of different crops' seeds. The use of nanoparticles to enhance seed quality has also produced outstanding results. According to recent research, nanoparticles enhance the vigour, quality and germination, of agricultural seeds, particularly groundnut seeds. (Shyla and Natarajan 2016),), onion (Anandaraj and Natarajan, 2017), greengram (Sangli *et al*., 2017) spinach. (Zheng *et al*.,2005), lettuce (Shah and Belozerova, 2009), tomato (Sridhar, 2012). and Peanut (Prasad *et al*., 2012).

IV. APPLICATION OF NANOTECHNOLOGY IN SEED SCIENCE

The seed is a nanogift from nature to man. It is a self-sustaining biological organism that can survive on its own in hostile conditions. Utilizing nanotechnology will enable seeds to reach their full potential. Especially for crops that are wind pollinated, producing seeds requires a lot of work. Genetic purity can be ensured by recognizing pollen loads that can cause contamination. Air temperature, humidity, wind speed, and crop pollen output all have an impact on pollen flight. Using bionanosensors designed to detect contaminating pollen can assist in locating possible contamination and reducing contamination as a result.

The same approach can be used to keep field crops from becoming contaminated by pollen from genetically engineered plants. New genes are inserted into seeds that are then sold on the market. Nanobarcodes, which are robust, machine-readable, encodeable, and sub-micron sized taggants, could be utilised to track sold seeds (Nicewarner Pena *et al*., 2001). Disease transmission through seeds, and infections usually ruin stored seeds. In addition to protecting seeds, nanoscale seed covers consisting of the elements Mn, Zn, Pa, Au, Pt, and Ag will also use a lot less material than current methods. Su and Li (2004) developed quantum dots (QDs), a flourescence marker combined with immuno-magnetic separation for E. coli 0157:H7, which may be used to distinguish between healthy and diseased seeds.

The application of insecticides and herbicides has been revolutionized by technologies like encapsulation and controlled release techniques. Smart seeds are seeds that have been nanoencapsulated with a particular bacterial strainIt will ensure proper field stand as a consequence, reduce the seed rate, and enhance crop performance. A smart seed that may be disseminated over a mountain range for regeneration can be set up to germinate when sufficient moisture is present (Natarajan and Sivasubramanian, 2007). Some potential focus areas of research are the use of bioanalytical nanosensors to assess seed ageing, the aerial distribution of seeds with magnetic coatings, finding moisture during storage and taking the appropriate measures to minimise damage. use of nano membranes to coat seeds, which detects the presence of water and allows seeds to absorb only when the moment suitable for germination. To enhance the germination of rainfed crops, a team of researchers is now experimenting with carbon nanotubes and metal oxide nanoparticles. Through greater moisture permeability, carbon nanotubes have been used, according to Khodakovskaya *et al.* (2009), to enhance tomato seed germination. According to their research, In order to allow water to permeate through the seed coat and enter the seeds, carbon nanotubes (CNTs) act as new pores. These procedures promote germination, which the rainfed agricultural system can use.

Some Other Applications

1. **Identifying Contamination in Seed Field:** Producing seeds is a time-consuming process in crops that are wind pollinated. By determining the pollen loads that may cause contamination, genetic purity can be guaranteed with precision. Pollen flight is influenced by factors such humidity, wind speed, air temperature, and crop pollen production. It is possible to identify potential contamination and subsequently limit it by using bio-nanosensors designed for contaminated pollen. Using the same method, it is possible to prevent field crops from being contaminated by pollen from GM plants. Nano-sensors that are tailored to a seed crop's pollen are provided by Michigan State University, USA, and aid to inform the seed farmer.

2. **Nanotechnology in Seed Health Management:** Seeds are shielded against infections by nanocoatings made of elemental Zn, Mn, Au, and Ag, among other metals. Seeds that have been treated with specific bio-agents and coated with nanoparticles will minimize seed rate, provide the best field stand, and enhance crop performance by reducing the diseases that are carried by both soil and seeds. Infections connected to seeds can be found using nano core shell biosensors that comprise protein-nanoparticles and protein-ligand (antigen). Nano biosensors can also be included into seed packs to detect insect activity by spotting the metabolites released by insects at an early stage. To handle infestations effectively, seeds can be applied to nano cores that have been coated with insecticides. These additionally, nano cores may be altered to create programmed "gut busters" that only release pesticides in alkaline environments, like the stomach of an insect.

3. **Nano Seed Biotechnology:** A new set of tools is provided by nanotechnology. for delivering and altering genes through the use of nanoparticles, nanocapsules and nanofibres, Nanomaterials when properly functionalized have the potential to act as carriers for variety genes as well as agents that can stimulate gene expression or control the dissemination of genetic information throughout plants. Such tailored gene delivery to seeds may be exploited for transient gene expression for only one generation at the target area. Genetic engineering could perhaps be advanced to the atomic level thanks to nanotechnology. Atomic engineering may be able to reorganise the DNA in seeds to produce various plant phenotypes, such as growth season, yield and colour, using a mutation method based on nanotechnology, Chaing Mai University in Thailand developed a white grain rice variety from a typical purple grain type. This process involved drilling a nano-sized hole in embryos and bombarding them with N2 + ions, which caused the genome to rearrange and changed the phenotype of the rice variety. By using radio nano-frequency tags to identify the GMO event and a specially adapted processing unit with sensors to detect it, it is possible to distinguish GM seeds from normal seeds. This allows for the removal of GMO seeds from seed lots.

4. **Nano Barcode Technology:** These days, noval genes are added to seeds before being sold. Selling seeds could be tracked using nanobarcodes, which are robust, computer-readable, encodeable, and sub-micron sized tags (Nicewarner Pena *et al.*, 2001). Barcodes

are becoming the most often used marketing tool for products on both domestic and international markets. Barcodes are essentially horizontal black and white bars with digital signatures that may be scanned by an electronic code reader to provide product information. Nano-based bar codes have been created as a result of the development of nanotechnology, which may be able to monitor and control the quality of seed moving through the market in the same ways as conventional bar codes. These bar codes are created by electroplating metal at the nanoscale in the required pattern. The seed industry can use a nano barcoding system since seeds are now sold on the market with novel genes introduced into them in the era of proprietary rights. In order to track breeder, foundation, and certified seeds with all pertinent data, such as lot number, producer name, varietal details, parentage information, when the seeds were tested and its complete findings, etc., nano barcodes can also be affixed to seed packets.

5. **Nano sensors for seed storage:** A variety of gases are released by seeds when they are in storage, depending on how old the seeds are. Electronic nose (E-nose) can determine the quantity of an odorant while detecting a variety of gases. Such volatile aldehydes can be found, and seeds that are beginning to deteriorate can be separated and reenergized before being used.

   In the near future, scientists hope to create a plastic bag for storing that is lined with nanoparticles.

6. **Coating with Nano polymer:** Using a moisture-sensitive nano polymer barrier to coat seeds will allow them to take in water only when it is optimal for germination, or when there is 45–50% moisture availability (Korishettar *et al.*, 2016).

V. IMPACT OF CARBON NANOTUBE ON SEED QUALITY

According to Khodakovskaya *et al.* (2009) Tomato seeds may germinate much more quickly and produce more biomass because thick seed covers may be penetrated by carbon nanotubes (CNTs) and support the seeds' water intake. Multiwalled Carbon Nano Tubes (MWCNT) have been suggested by researchers to have positive effects was caused by CNTs capacity to pierce seed covering and so promote water uptakeWater consumption during seed germination is essential because mature seeds are extremely dry and need a lot of water to begin cell metabolism and development. The idea was confirmed by the measured seeds' water content and the presence of CNTs inside of seeds, but no information was provided regarding the particular methods by which the seeds' coats were penetrated or how the CNTs improved water uptake. According to Canas *et al.* (2008), over the course of 24 to 48 hours, In tomato, lettuce, cabbage, and carrot, single-walled carbon nanotubes (SWCNTs) dramatically reduced root elongation, but enhanced growth in onion and cucumber. Among the six examined species, tomato had the greatest level of sensitivity to SWCNTs. Carbon nanotubes were shown to improve seed germination in Nair et al.'s (2010) study of the impact of both SWCNTs and MWCNTs (multi walled carbon nanotubes) on the germination of rice seeds.. According to Yugandhar and Savithramma (2013), CCNPs speed up seed germination and seedling growth. They found that CCNPs produced the highest germination rates (92%), seedling vigour indexes (892), root and shoot lengths (2.3 cm and 7.4 cm), and seedling dry weights (212 mg) in comparison to controls. Fullerene, carbon nanotubes, and metal oxide nanoparticles are harmful, However, Brassica juncea and Phaseolus mungo seedling development are positively impacted by multi-walled carbon nanotubes (MWCNTs)

(Ghodake et al., 2010). In wheat, maize, peanuts, and garlic, it was claimed that multiwall carbon nanotubes (MWCNTs) were able to enter the seed coat by forming new pores. According to Anita and Rao (2014), this enhanced water intake and significantly boosted seed germination, plant development, and biomass when compared to control. The researchers came to the conclusion that plant cell walls serve as a barrier for the entry of any external substances, including nanoparticles, into plant cells since the sieving capabilities were determined by the pore width of the cell wall, which ranged from 5 to 20 nm. As a result, only particles or aggregates of particles with a diameter smaller than the Dimensions of the cell wall's pores Consequently, they are easily able to penetrate and reach the plasma membrane. It was also hypothesised that interacting with designed nanoparticles would stimulate the formation new or expanded cell wall pores, which would enhance the uptake of nanoparticles.(Navarro *et al*.,2008).

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