Nano technology related to its impact on seed and Agriculture

Nanotechnology deals with substances that are measured in billionths of a meter because the word "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, nanotechnology has the potential to increase agricultural output. The potential is expanding with the development of efficient techniques and sensors for precision agriculture, resource management, early disease and contaminant 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. Future developments in nanotechnology, which will also benefit consumers, producers, farmers, ecosystems, and society at large, are anticipated to be the main drivers of this industry's long-term economic growth.

Currently, nanotechnology—a young, exciting subject of science—is useful in many fields. Both the field of biotechnology and agriculture can greatly benefit from it. The science and art of controlling matter at the nanoscale is known as nanotechnology. Nanotechnology deals with the manipulation of materials that have at least one dimension and have sizes between 1 and 100 nanometers. A nanometre (nm) is one billionth of a meter, or 10-9 m. Without the use of agrochemicals like pesticides, fertilizers, etc., modern agriculture cannot produce food sustainably or efficiently. However, each agrochemical has certain potential drawbacks, such as the possibility of contaminating water supplies or leaving residues on food products that are hazardous to human and environmental health (Kah, 2015). As a result, careful management and control of inputs may be able to reduce these risks. In order to feed the expanding population, the world population is expanding at an accelerating rate. Use of contemporary or innovative methods that can boost production and improve quality in agriculture is required. The establishment of an alternative method utilizing engineered smart 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, food quality, plant protection, 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 goal 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 high surface area.
- Materials' strength or electrical properties, increasing their reactivity to chemicals
- Materials' physical, chemical, and biological characteristics differ from those of their 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.
- Attach to the membrane through electrostatic contact, causing the membrane's integrity to be compromised.

Nanoparticles

Materials with at least two dimensions and a size between 1 and 100 nm are known as nanoparticles (NPs) (Ball, 2002**).** Now, the question "Why 100 nm and not 150 nm?" or "Why not 1 to 1 000 nm?" arises. This is due to the definition's emphasis on how a dimension affects a particular substance. Rather of determining the precise dimension at which this impact originates, consider the emergence of quantum phenomena. Nanoscience is not merely the study of tiny particles; it is also the study of how small-scale materials exhibit size-dependent quantum effects, which are fundamentally different 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 differs from bulk material in that a large number of its atoms are located on the surface. Nanoparticles may differ from macroparticles in terms of surface composition, site types and densities, and reactivity towards chemical reactions like adsorption and redox reactions (Waychunas *et al*., 2005; Hochella *et al*., 2008). These differences could be used to create nanomaterials to enhance seed quality.

Improving seed quality through nanotechnology

In addition to easily measurable traits like viability, seed lot purity, health, and mechanical damage, vigour, 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 enhance the quality of different crops' seeds. The use of nanoparticles to enhance seed quality has also produced outstanding results. According to recent research, nanoparticles improved the vigour, germination, and quality of agricultural seeds, particularly groundnut seeds. (Shyla and Natarajan 2016), greengram (Sangli *et al*., 2017), onion (Anandaraj and Natarajan, 2017), lettuce (Shah and Belozerova, 2009), spinach. (Zheng *et al*.,2005), peanut (Prasad *et al*., 2012) and tomato (Sridhar, 2012).

Application of nanotechnology in seed science

Nature's nano-gift to man is the seed. It is a self-sustaining biological entity that can live alone in hostile conditions. Utilizing nanotechnology will enable seeds to reach their full potential. It takes a lot of work to produce seeds, especially for crops that are wind pollinated. Genetic purity can be assured by identifying pollen loads that will lead to contamination. Air temperature, humidity, wind speed, and crop pollen production all influence pollen flight. Utilizing bionanosensors designed to detect contaminating pollen can assist identify potential contamination and hence lower contamination.

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 durable, machine-readable, encodable, and sub-micron sized taggants, could be used to track sold seeds (Nicewarner Pena *et al*., 2001). Disease spreads through seeds, and infections frequently destroy stored seeds. Using elemental forms of Zn, Mn, Pa, Pt, Au, and Ag in nanoscale seed coatings will not only protect seeds but also utilise far less material than is now done. Quantum dots (QDs), a flourescence marker combined with immuno-magnetic separation for E. coli 0157:H7, were created by Su and Li (2004) and will be useful for separating viable and infected 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 strain. As a result, it will assure proper field stand, lower the seed rate, and improve crop performance. A smart seed that may be disseminated over a mountain range for regeneration can be programmed to germinate when sufficient moisture is present (Natarajan and Sivasubramanian, 2007). Aerial broadcasting of seeds embedded with magnetic particles, detecting the moisture content during storage to take appropriate action to reduce damage, and use of bioanalytical nanosensors to determine ageing of seeds are some potential thrust areas of research. Coating seeds with nano membrane, which senses the availability of water and allows seeds to imbibe only when time is right 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, carbon nanotubes (CNTs) behave as new pores for water permeation through the seed coat and as a conduit for water to be channelled into the seeds. These procedures promote germination, which the rainfed agricultural system can use.

Some other applications

Detecting 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 en flight is affected by air temperature, humidity, wind speed, and crop pollen generation. 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.

Nanotechnology in seed health management

Seeds are shielded against infections by nanocoatings made of elemental Zn, Mn, Au, and Ag, among other metals. By controlling the pathogens that are carried by both seeds and soil, seeds that have been coated with nano particles and enclosed in particular bio-agents will lower seed rate, guarantee the best field stand, and improve crop performance. For the detection of infections connected to seeds, nano core shell biosensors with protein-ligand (antigen) and protein-nanoparticles can be used. By detecting the metabolites emitted by insects at an early stage, nano biosensors can also be incorporated into seed packets to detect insect activity. To handle infestations effectively, seeds can be applied to nano cores that have been coated with insecticides. These nano cores can also be modified into programmable devices known as "gut busters" that only release insecticides in alkaline settings, such as the stomach of an insect.

Nano seed biotechnology

Nanotechnology offers a new set of tools for delivering and altering genes through the use of nanoparticles, nanofibres, and nanocapsules. Nanomaterials can act as carriers for various genes as well as substances that can stimulate gene expression or control the dissemination of genetic information throughout plants when they are correctly functionalized. For transitory gene expression for only one generation at the target region, such targeted gene delivery to seeds may be used. Genetic engineering could perhaps be advanced to the atomic level thanks to nanotechnology. Rearranging the DNA in seeds to create different plant phenotypes, such as colour, growth season, and yield, may be achievable through atomic engineering. In Thailand, Chaing Mai University created a white grain rice variety from a traditional purple grain variety using a nanotechnology-based mutation process. 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.

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. The development of nanotechnology has led to the creation of nano-based bar codes, which may perform the same tasks as traditional bar codes for monitoring and regulating the quality of seed going through the market. These bar codes are created by electroplating metal at the nanoscale in the required pattern. As seeds are now sold on the market with novel genes inserted into them in the era of proprietary rights, the seed industry can use a nano barcoding system. In order to track breeder, foundation, and certified seeds with all pertinent data, such as lot number, producer name, varietal details, parentage information, date of seed testing and its full results, etc., nano barcodes can also be affixed to seed packets.

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 storage bag that is lined with nanoparticles.

Nano polymer coating

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).

Effect of carbon nanotube on seed quality

According to Khodakovskaya *et al*. (2009), carbon nano tubes (CNTs) may penetrate thick seed coats and support water uptake by the seeds, which may be the reason tomato seeds germinate substantially more quickly and produce more biomass. The researchers proposed that the ability of CNTs to penetrate seed coats and so encourage water uptake was the source of the beneficial effect of multi-walled Carbon Nano Tubes (MWCNT). Because mature seeds are very dry and require a significant amount of water to start cellular metabolism and growth, water intake during seed germination is crucial. The idea was confirmed by the measured water content of seeds and the presence of CNTs inside 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), Single Walled Carbon Nano Tubes (SWCNTs) dramatically reduced root elongation in tomato, lettuce, cabbage, and carrot over the course of 24 to 48 hours, but increased growth in onion and cucumber. Among the six examined species, tomato had the greatest level of sensitivity to SWCNTs. Nair *et al*. (2010) investigated the effects of both SWCNTs and MWCNTs (multi walled carbon nanotubes) on the germination of rice seeds and discovered that carbon nanotubes increased seed germination. 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 multi-walled carbon nanotubes, or MWCNTs, have a beneficial effect on the germination and seedling growth of Brassica juncea and Phaseolus mungo (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. This improved water uptake and markedly increased seed germination, plant growth, and biomass when compared to control (Anita and Rao, 2014). As the sieving properties were dictated by the cell wall's pore diameter, which ranged from 5 to 20 nm, the researchers concluded that plant cell walls act as a barrier for the entry of any external substances, including nanoparticles, into plant cells. As a result, only particles or aggregates of particles having a diameter smaller than the pore diameter of the cell wall may easily pass through and reach the plasma membrane. It was also hypothesised that interacting with designed nanoparticles would cause cell wall pores to grow or form new ones, which would improve the uptake of nanoparticles.(Navarro *et al*.,2008).

Reference

Anandaraj, K., & Natarajan, N. (2017). Effect of nanoparticles for seed quality enhancement in onion [*Allium cepa* (Linn) cv. CO (On)] 5. *Int J Curr Microbiol App Sci*, *6*, 3714-3724.

Ball, P. (2002). Natural strategies for the molecular engineer. *Nanotechnology*, *13*(5), R15.

Cañas, J. E., Long, M., Nations, S., Vadan, R., Dai, L., Luo, M., & Olszyk, D. (2008). Effects of functionalized and nonfunctionalized single-walled carbon nanotubes on root elongation of select crop species. *Environmental Toxicology and Chemistry: An International Journal*, *27*(9), 1922-1931.

Ghodake, G., Seo, Y. D., Park, D., & Lee, D. S. (2010). Phytotoxicity of carbon nanotubes assessed by Brassica juncea and Phaseolus mungo. *Journal of Nanoelectronics and Optoelectronics*, *5*(2), 157-160.

Kah, M. (2015). Nanopesticides and nanofertilizers: emerging contaminants or opportunities for risk mitigation?. *Frontiers in chemistry*, *3*, 64.

Khodakovskaya, M., Dervishi, E., Mahmood, M., Xu, Y., Li, Z., Watanabe, F., & Biris, A. S. (2009). Carbon nanotubes are able to penetrate plant seed coat and dramatically affect seed germination and plant growth. *ACS nano*, *3*(10), 3221-3227.

Korishettar, P., Vasudevan, S. N., Shakuntala, N. M., Doddagoudar, S. R., Hiregoudar, S., & Kisan, B. (2016). Seed polymer coating with Zn and Fe nanoparticles: An innovative seed quality enhancement technique in pigeonpea. *Journal of Applied and Natural Science*, *8*(1), 445-450.

Liu, R., & Lal, R. (2015). Potentials of engineered nanoparticles as fertilizers for increasing agronomic productions. *Science of the total environment*, *514*, 131-139.

Mandal, A. K., De, B. K., Saha, R., & Basu, R. N. (2000). Seed invigoration treatments for improved storability, field emergence and productivity of soybean (*Glycine max* (L.) Merrill. *Seed Science and Technology (Switzerland)*, *28*(2), 349-355.

Maurice, P. A., & Hochella, M. F. (2008). Nanoscale particles and processes: a new dimension in soil science. *Advances in agronomy*, *100*, 123-153.

Murthy UMN, Kumar PP, Sun WQ. (2003) Mechanisms of seed ageing under different storage conditions for *Vigna radiata* (L.) Wilczek: Lipid peroxidation, sugar hydrolysis, Maillard reactions and their relationship to glass state transition. *J Exp. Bot*.; 54:1057-1067.

Nair, R., Varghese, S. H., Nair, B. G., Maekawa, T., Yoshida, Y., & Kumar, D. S. (2010). Nanoparticulate material delivery to plants. *Plant science*, *179*(3), 154-163.

Natarajan, N., & Sivasubramaniam, K. (2007). Nanotechnology application in seed management. *Application of Nanotechnology in Agriculture, CR Chinnamuthu, B. Chandrasekaran, and C. Ramasamy (Eds), Tamil Nadu Agricultural University, Coimbatore, India*.

Navarro, E., Baun, A., Behra, R., Hartmann, N. B., Filser, J., Miao, A. J., & Sigg, L. (2008). Environmental behavior and ecotoxicity of engineered nanoparticles to algae, plants, and fungi. *Ecotoxicology*, *17*, 372-386.

Nicewarner-Pena, S. R., Freeman, R. G., Reiss, B. D., He, L., Peña, D. J., Walton, I. D.,& Natan, M. J. (2001). Submicrometer metallic barcodes. *Science*, *294*(5540), 137-141.

Perry, D. A. (1980). The concept of seed vigour and its relevance to seed production techniques.

Prasad, T. N. V. K. V., Sudhakar, P., Sreenivasulu, Y., Latha, P., Munaswamy, V., Reddy, K. R., .& Pradeep, T. (2012). Effect of nanoscale zinc oxide particles on the germination, growth and yield of peanut. *Journal of plant nutrition*, *35*(6), 905-927.

Sagili JLRS, Roopa Bai, Sharanagouda H, Ramachandra CT, Sushila Nadagouda, Shivanagouda Doddagoudar R. (2017). Biosynthesis and Characterization of ZnO Nanoparticles from Spinach (Spinacia oleracea) Leaves and Its Effect on Seed Quality Parameters of Greengram (*Vigna radiata*). *Int. J Curr. Microbiol. App. Sci*.; 6(9):3376-3384.

Sekhon, B. S. (2014). Nanotechnology in agri-food production: an overview. Nanotechnol Sci Appl 7: 31–53.

Shah, V., & Belozerova, I. (2009). Influence of metal nanoparticles on the soil microbial community and germination of lettuce seeds. *Water, air, and soil pollution*, *197*, 143-148.

Shyla KK, Natarajan N. (2016).Synthesis of inorganic nanoparticles for the enhancement of seed quality in groundnut cv. VRI-2. *Adv. Res. J Crop Improv*.; 7(1):32-39.

Sridhar, C. (2012). Effect of nanoparticles for the maintenance of tomato seed vigour and viability. *M. Sc.(Agri.) Thesis*.

Srivastava, A., & Rao, D. P. (2014). Enhancement of seed germination and plant growth of wheat, maize, peanut and garlic using multiwalled carbon nanotubes. *Eur Chem Bull*, *3*(5), 502-504.

Su, X. L., & Li, Y. (2004). Quantum dot biolabeling coupled with immunomagnetic separation for detection of escherichia c oli O157: H7. *Analytical chemistry*, *76*(16), 4806-4810.

Waychunas, G. A., Kim, C. S., & Banfield, J. F. (2005). Nanoparticulate iron oxide minerals in soils and sediments: unique properties and contaminant scavenging mechanisms. *Journal of nanoparticle research*, *7*, 409-433.

Yugandhar, P., & Savithramma, N. (2013). Green synthesis of calcium carbonate nanoparticles and their effects on seed germination and seedling growth of *Vigna mungo* (L.) Hepper. *Int J Adv Res*, *1*(8), 89-103.

Zheng, L., Hong, F., Lu, S., & Liu, C. (2005). Effect of nano-TiO 2 on strength of naturally aged seeds and growth of spinach. *Biological trace element research*, *104*, 83-91.