JUST AGRICULTURE
multidisciplinary e-Newsletter

ARTICLE ID: 55

NANO REVOLUTION: TRANSFORMING AGRICULTURE WITH NANOTECHNOLOGY

Suryabhan[1*], Abhinav Yadav[1], Rajat Yadav[1], Mahendra Yadav[2]

[1]Research Scholar, Department of Agronomy, Chandra Shekhar Azad University of Agriculture & Technology, Kanpur, UP

[2]MSc, Department of Agronomy, Chandra Shekhar Azad University of Agriculture & Technology, Kanpur, UP

INTRODUCTION

Nanotechnology is One of the promising fields , which has the potential to increase food production and create new products for uses in agriculture, food, water, the environment, medical, energy, and electronics. It is a developing and rapidly growing reason with the new and exclusive applications in agricultural and food research. (Sadeghi *et al*.2017). Agriculture nanotechnology has been focused on research and application during the last few years to resolve the agriculture and environmental issues sustainability, agricultural enhancement, and increased productivity. Agricultural nanotechnology seems to be of great importance to poor countries. Regarding the reduction of hunger, undernourishment, and child mortality rates (Gogos *et al*., 2012).

Keywords: Nanotechnology, Sustainability, Precision Agriculture, Remote Sensing, Nanobiosensor.

DEFINITION OF NANOTECHNOLOGY

Nanotechnology is defined by the US Environmental Protection Agency19 as the science of understanding and control of matter at dimensions of roughly 1–100 nm, where unique physical properties make novel applications possible. This definition is slightly rigid In terms of size and dimension, The materials' capacity to solve problems may have received more attention. . Other attempts to define nano particles from the point of view of agriculture include "particles with a size range of 10 to 1,000 nm and which are also colloidal particles"

JUST AGRICULTURE
multidisciplinary e-Newsletter

FUNDAMENTALS OF NANOTECHNOLOGY

Nanotechnology means the "synthesis, designing, characterizing, and utilization of assemblies, tools, and systems via directing the morphology and size variation at nanometer level from 1 - 100 nm" (Yadollahi *et al*., 2010). For your reference, one nanometer-scale means one-billionth

(10^{-9}) of part of one meter which implies that the application of the technology at this size. nano science and nanotechnologies are regarded as creative attitudes in developmental research. When it comes to learning about the marvels and operations of substances at the atomic, molecular, or macromolecular levels, where their qualities are noticeably different from those at the bulk level (Potocnik. 2005).

ROLE OF NANO SENSORS IN AGRICULTURE:

Nanosensors, which are sensors with nano scale dimensions, have the potential to revolutionize agriculture by providing real-time and accurate information about crops, soil conditions, plant health, and environmental factors. Here are some key aspects of nano sensors in agriculture:

1. **Crop Monitoring:**

Crop monitoring is essential for optimizing agricultural practices and maximizing crop yield. Nano sensors offer several advantages in crop monitoring:

- **Real-time Monitoring:** Nano sensors enable continuous and real-time monitoring of various parameters, such as temperature, humidity, light intensity, and nutrient levels in the soil and surrounding environment. This data can help farmers make informed decisions regarding irrigation, fertilization, and pest management.
- **Precision Agriculture:** Nanosensors enable precise monitoring at a localized scale, allowing farmers to apply inputs, such as water and fertilizers, precisely where they are needed. This approach reduces resource wastage and improves overall efficiency.
- **Remote Sensing:** Nanosensors can be integrated into remote sensing platforms, such as drones or satellites, to monitor large agricultural areas efficiently. These sensors can capture multispectral or hyperspectral data, providing insights into crop health, stress levels, and growth patterns.

2. **Soil Analysis:** Soil analysis is crucial for understanding soil fertility, nutrient content, moisture levels, and pH, among other parameters. Nano sensors offer the following benefits for soil analysis:

- **Nutrient Monitoring:** Nano sensors can detect and quantify nutrient levels in the soil, including nitrogen, phosphorus, and potassium. This information helps farmers optimize fertilizer application and prevent nutrient deficiencies or excesses.
- **Soil Moisture Monitoring:** Nano sensors can measure soil moisture content accurately. This data allows farmers to schedule irrigation more efficiently, ensuring that crops receive adequate water without wasting resources.
- **pH and Salinity Monitoring:** Nano sensors can assess soil pH levels and salinity, which are critical factors affecting crop growth. Monitoring these parameters helps farmers make necessary adjustments to optimize soil conditions for plant growth.

3. **Nano fertilizers and Nutrient Management**

- **Nano-sized nutrient particles:** These nanofertilizers involve the use of nanoparticles that contain essential nutrients, such as nitrogen, phosphorus, or potassium. The nanoparticles provide a high surface area-to-volume ratio, allowing for better nutrient absorption by plant roots.
- **Coating-based nano fertilizers:** In this approach, nanoparticles are coated with nutrient compounds, such as urea or phosphate. The coatings protect the nutrients from leaching and provide controlled-release properties, ensuring a gradual release of nutrients over time.

4. Controlled-Release Nano fertilizers:

- **Coating-based systems:** Nano fertilizers can be coated with polymers or other materials that control the release rate of nutrients. The coatings can be engineered to respond to specific environmental factors like temperature, soil moisture, or microbial activity.
- **Nanocarrier-based systems:** Nutrients can be encapsulated within nanoscale carriers, such as micelles, liposomes, or nanoparticles. The release of nutrients is

controlled by the carrier properties, such as the degradation rate or response to external stimuli.

- **Nanoporous systems:** Nanofertilizers can be designed with nanoporous structures that provide controlled nutrient release through diffusion or desorption processes. The pore size and structure can be tailored to achieve the desired release kinetics.

5.0 NANO PESTICIDES AND CROP PROTECTION

5.1 Nanotechnology to Pest Management

In modern agricultural practices Pest management techniques primarily depend on the use of pesticides such as insecticides, fungicides, and herbicides. It is critical to create environmentally friendly, high-performing pesticides that are also cost-effective. The new concepts such as nanotechnology can offer advantages to pesticides, like minimizing the toxicity, increasing the shelf life, and making less water-soluble pesticides more soluble, all of which could have positive impacts on the environment.(Mali *et al*., 2020; Worrall *et al*., 2018).

Nanotechnology provides tools to design and develop novel approaches that can enhance the effectiveness and efficiency of pest control while minimizing the use of conventional pesticides. Some nanotechnology-based approaches include:

- **Nanosensors:** Nanosensors can detect and monitor pests, diseases, and environmental conditions in real-time, allowing farmers to take timely and targeted action. These sensors can detect specific molecules released by pests or pathogens, enabling early detection and response.
- **Nanobiosensors:** Nanobiosensors combine nanotechnology with biological components to detect pests, pathogens, or pesticide residues. They can provide highly sensitive and specific detection capabilities, facilitating rapid and accurate pest identification.
- **Nanoencapsulation:** Nanoencapsulation involves packaging active ingredients, such as pesticides or beneficial compounds, within nanoscale carriers. This approach can improve the stability, controlled release, and targeted delivery of pesticides, reducing their environmental impact and enhancing their efficacy.

- **Nanopesticides:** Nanopesticides are formulations where the active ingredients are at the nanoscale. These formulations can enhance the bioavailability and persistence of pesticides, leading to improved pest control while using lower doses.

5.1 Nano pesticides for Disease Control: Nanotechnology has shown promise in disease control by developing nano pesticides. These nano scale formulations can improve the effectiveness and efficiency of disease management strategies. Some potential applications of nano pesticides for disease control include:

- **Controlled release:** Nanocarriers can provide controlled release of pesticides, ensuring a sustained and prolonged effect against pathogens. This approach enhances the efficiency of disease control measures by reducing the need for frequent applications.
- **Improved disease resistance:** Nano pesticides can also be designed to enhance the plant's natural defense mechanisms against diseases. They can stimulate the plant's immune response, making it more resistant to pathogen attacks.
- **Reduced environmental impact:** The use of nano pesticides can potentially reduce the environmental impact associated with conventional pesticide use. By using lower doses and targeted delivery systems, nanotechnology minimizes the release of pesticides into the environment, thereby mitigating ecological risks.

ADVANTAGES OF NANO TECHNOLOGY IN AGRICULTURE

Nanotechnology offers several advantages in agriculture, revolutionizing the way we address various challenges in the field. Some of the key advantages include:

1. Nano particles can be designed to deliver nutrients, fertilizers, and pesticides directly to plant roots or targeted locations. This targeted delivery system helps reduce wastage and ensures plants receive the required nutrients more efficiently, leading to increased crop yield.

2. Nano sensors can be used to monitor soil moisture levels, helping farmers optimize irrigation practices. This ensures that water is used more efficiently, reducing water waste and conserving this precious resource.

3. Nano particles can be engineered to deliver pesticides, fungicides, and other crop protection agents directly to the affected areas of plants. This targeted approach reduces the amount of chemicals needed, minimizing environmental impact while effectively managing pests and diseases.

4. Nano structured materials can help enhance soil properties, such as water retention, nutrient retention, and soil structure. This can lead to improved soil fertility and long-term sustainable agriculture practices.

5. Nanotechnology allows for precise monitoring and management of agricultural processes. Nano sensors can provide real-time data on soil conditions, plant health, and environmental factors, enabling farmers to make data-driven decisions to optimize crop production.

6. Increased crop yield and quality By addressing various agricultural challenges, nanotechnology can significantly improve crop yield and quality. This can lead to increased food production to meet the demands of a growing global population.

7. Targeted delivery of agrochemicals and optimized resource utilization lead to reduced environmental pollution, soil degradation, and water contamination. This promotes sustainable agricultural practices that are beneficial for the environment in the long term.

8. Nanotechnology can aid in the development of genetically modified crops by facilitating the delivery of genes or RNA molecules directly to plant cells. This can accelerate the process of developing new crop varieties with desirable traits, such as disease resistance or increased nutritional value.

9. Nanotechnology can extend the shelf life of agricultural products by using nanocoatings or nanomaterials that slow down spoilage processes and inhibit microbial growth, leading to reduced food wastage.

FUTURE PERSPECTIVES

Nano-agriculture is an evolving field that holds great potential for transforming agriculture practices. Some emerging trends in nano-agriculture include:

- **Nano-fertilizers:** Nano-sized fertilizers can enhance nutrient uptake efficiency, reduce nutrient losses, and improve crop yields. They can be designed to release nutrients gradually, ensuring optimal availability for plants.
- **Nano-pesticides:** Nano-formulations of pesticides can improve their effectiveness by enhancing their penetration into plant tissues or targeting specific pests while minimizing environmental impact.
- **Nano-sensors:** Nanotechnology can enable the development of advanced sensors for monitoring soil moisture, nutrient levels, and crop health. These sensors can provide real-time data for precision agriculture and optimal resource management.
- **Nano-encapsulation of bioactive compounds:** Nanoencapsulation techniques can protect and deliver bioactive compounds, such as vitamins or plant growth regulators, to enhance plant health and productivity.
- **Nanomaterials for soil remediation:** Certain nanomaterials can aid in the removal of contaminants from soil, reducing soil pollution and improving its fertility.

CHALLENGES TO ADOPTION OF NANO TECHNOLOGY

While nano-agriculture shows promise, there are several challenges that need to be addressed for widespread adoption. Some of these barriers include:

- **Cost:** The development and production of nano materials can be expensive, making them less accessible to farmers, particularly in resource-limited settings. Efforts should be made to optimize manufacturing processes and reduce production costs.
- **Regulatory concerns:** The safety and environmental impact of nano-agricultural products need to be thoroughly assessed and regulated to ensure their responsible use. Robust guidelines and regulations should be in place to address any potential risks.
- **Knowledge and awareness:** Farmers and stakeholders need to be educated about the potential benefits and risks of nano-agriculture. Training programs and awareness campaigns can help disseminate knowledge and build trust.

JUST AGRICULTURE
multidisciplinary e-Newsletter

- **Scale-up and integration:** Scaling up nano-agricultural technologies from laboratory research to large-scale implementation can be challenging. Integration with existing agricultural practices and infrastructure should be considered for seamless adoption.

References:

1. **Gogos, A., Knauer, K., Bucheli, T.D., (2012).** Nano materials in plant protection and fertilization: current state, foreseen applications, and research priorities. *J. Agric. Food Chem*. **60**:9781–9792.
2. **Mali, S.C., Raj, S., Trivedi, R., (2020).** Nanotechnology a novel approach to enhance crop productivity. *Biochem. Biophys. Rep*. 24 **,**
3. **Potocnik, J., (2005)**. Nano sciences and Nanotechnologies: an Action Plan for Europe 2005-2009. *Commission of the European Communities, Brussels*, pp. 1–16.
4. **Sadeghi, R., Rodriguez, R.J., Yao, Y., Kokini, J.L., (2017).** Advances in nanotechnology as they pertain to food and agriculture: benefits and risks. Annu. Rev. *Food Sci. Technol.* **8**, 467 -492.
5. **Worrall, E.A., Hamid, A., Mody, K.T., Mitter, N., Pappu, H.R.,(2018).** Nanotechnology for plant disease management. Agronomy **8** (12): 285.
6. **Yadollahi, A., Arzani, K., Khoshghalb, H., (2010)**. The role of nanotechnology in horticultural crops postharvest management. In: *Southeast Asia Symposium on Quality and Safety of Fresh and Fresh-Cut Produce*, **875**: 49–56.