SSR Inst. Int. J. Life Sci.
ISSN (O): 2581-8740 | ISSN (P): 2581-8732
Choudhary *et al.*, 2023
DOI: 10.21276/SSR-IIJLS.2023.9.3.3

Review Article

open access

Applications of Nanoparticles in Agriculture Improvement-A Review

Sandeep Kumar Choudhary[1], Pratap Chand Mali[2*], Ram Niwas Jangir[3], Shashi Meena[3], Rahul Tiwari[4]

[1]Post Doctoral Fellow, RUSA2.0, Department of Zoology, Centre for Advanced Studies, University of Rajasthan, Jaipur, India

[2]PI RUSA Thematic Project No. 5, Department of Zoology, Centre for Advanced Studies, University of Rajasthan, Jaipur, India

[3]Assistant Professor, Department of Zoology, Centre for Advanced Studies, University of Rajasthan, Jaipur, India

[4]Veterinarian, RUSA2.0, Department of Zoology, Centre for Advanced Studies, University of Rajasthan, Jaipur, India

***Address for Correspondence:** Prof. Pratap Chand Mali, Reproductive Biomedicine and Natural Product Lab, Department of Zoology, Centre for Advanced Studies, University of Rajasthan, Jaipur-302004, India
E-mail: malipc_zool@yahoo.co.in

Received: 17 Jan 2023/ Revised: 23 Mar 2023/ Accepted: 29 Apr 2023

ABSTRACT

The field of nanotechnology is quickly developing and emerging since it has enormous potential for various human uses. With their unique, size-based physical and chemical attributes, nonmaterials generated and engineered through nanotechnology have many applications in biomedicine and agriculture. Theranostics is a branch of nanomedicine that uses small, highly surface-area nanoparticles to diagnose and treat diseases. Nanomaterials have a wide range of uses in agriculture, from fertilizers that improve soil nutrient uptake by plants to nano pesticides that control a variety of pests, including fungi, phytophagous insects, and weeds, increasing food output. Agriculture and food security are intimately connected, and many researchers are interested. Agriculture production depends on many difficulties due to the severe effects of climate change, water problems and changing the distribution of insect pests.

Meanwhile, it faces tremendous challenges in maintaining food security for a massive population amid declining resources. Research is actively exploring the use of nonmaterial in agriculture due to their tremendous promise. Despite their good qualities, nonmaterial present risks to the environment and human health, necessitating risk assessment studies. Green nonmaterial synthesis may lessen the usage of toxic agrochemicals that pollute the environment and enter biological systems, providing an environmentally safe, environmentally friendly, and economically advantageous option. In this critical evaluation, nanoparticles are used in agriculture.

Key-words: Agriculture, Biomedicine, Insects, Nanoparticles, Nanotechnology

INTRODUCTION

Japanese scientist Norio Taniguchi coined the word nanotechnology, and it is now considered a promising multidisciplinary field with great promise in both the medical and agricultural sectors [1]. Nanotechnology is the subject of understanding, creating, and managing matter with a size between one and one hundred nanometers.

How to cite this article

Choudhary SK, Mali PC, Jangir RN, Meena S, Tiwari R. Applications of Nanoparticles in Agriculture Improvement- A Review. SSR Inst. Int. J. Life Sci., 2023; 9(3): 3223-3228.

Access this article online
https://iijls.com/

As a result of the unique properties of matter at the nanoscale, the technique can be used to create materials with novel applications across a wide range of industries. According to Laurent et al. [2], nanoparticles (NPs) are incredibly small materials composed of carbon, metal oxides, metal, or organic matter with at least one dimension of less than 100 nm. It is possible to manufacture NPs using nanotechnology.

They can be divided into four categories based on their dimensionality: zero, one, two, and three [3]. They can also be divided into groups according to their chemical, physical, and compositional characteristics: Carbon-based, organic, and inorganic Nanoparticles. Due to the impact that size has on the physiochemical

ISSN (O): 2581-8740 | ISSN (P): 2581-8732
Choudhary *et al.*, 2023
DOI: 10.21276/SSR-IIJLS.2023.9.3.3

characteristics of matter, these materials are incredibly fascinating due to their ability to tune properties of interest precisely. The surface to volumes ratio of these materials is also a major factor in their high reactivity. These qualities in both agriculture and medicine make them ideal candidates for developing novel products. In the past few decades, nanomedicine has evolved as a brand-new field of medicine that uses nanotechnology for the early detection, better diagnosis, and treatment of several disorders. The already available nanomedicine devices cover various uses, from bioimaging and diagnostics to medication delivery and medicines. For quick disease diagnostics and molecular-level disease management, several nanomaterials are already being used as alternative tools [4].

Nanotechnology is also impacting agriculture, which is the backbone of most developing countries. Food production relies heavily on chemical fertilizers and pesticides to meet global demand and protect crops, which causes environmental contamination and health problems. Innovations in nanotechnology have merged seamlessly with traditional agricultural practices to promote sustainable agriculture. By combining nanotechnology and agrochemicals, nano-agrochemicals have transformed agriculture with products like nano fertilizers, nano pesticides, nano insecticides, nano fungicides, and nano herbicides. Nanoagrochemicals are eco-friendly and cheaper than conventional agrochemicals because they are more efficient.

Further, farmers benefit from the increased quantity and quality of crops. Although nano agrochemicals have several benefits, they have yet to reach their full potential. Among the major obstacles to nanoparticles' global acceptance are environmental and human health safety concerns linked to their tendency to accumulate in living systems and the environment. It has been shown that NPs can harm living cells, causing genotoxicity, cell death, metaplasia, inflammation, hypertrophy, and even carcinogenesis [5] primarily because they make reactive oxygen species [6]. In the present review, the uses, and applications of nanoparticles in biomedicine for the control, diagnosis and treatment of various diseases and agriculture for controlling and managing pest and crop production (Fig. 1).

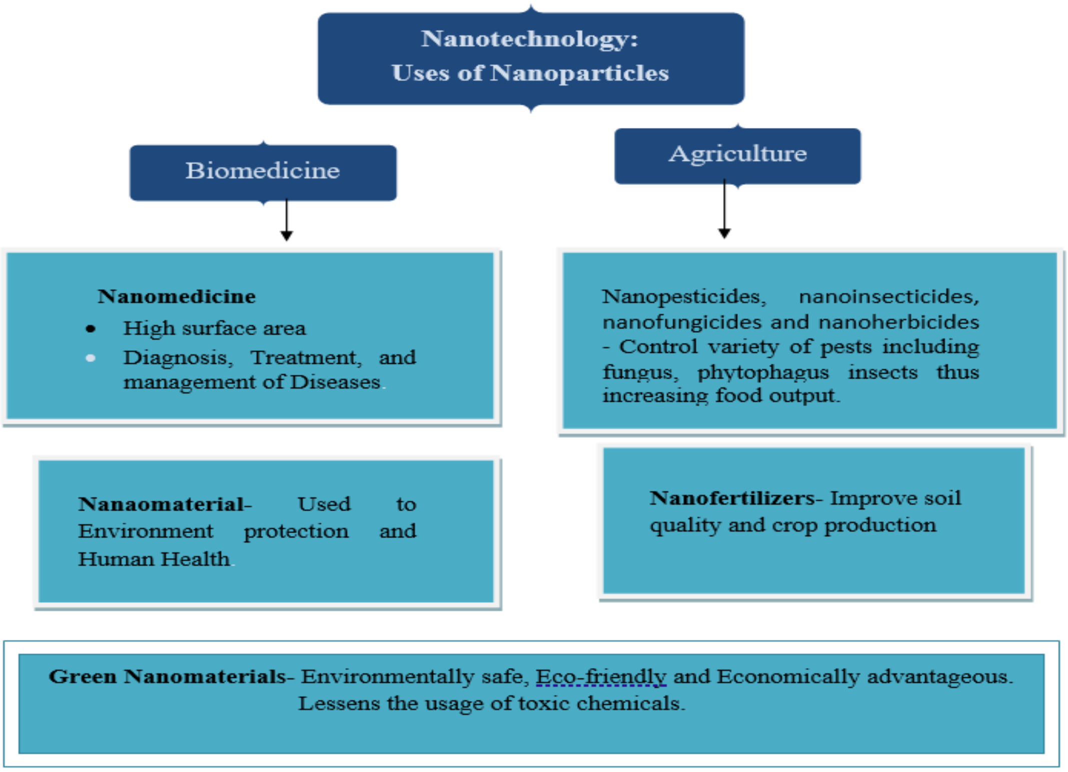

Fig. 1: Application of Nanotechnology in Biomedicine and Agriculture

ISSN (O): 2581-8740 | ISSN (P): 2581-8732
Choudhary *et al*., 2023
DOI: 10.21276/SSR-IIJLS.2023.9.3.3

Uses and applications of Nanoparticles in Agriculture- Agriculture is the main source of livelihood for most developing countries. Agriculture is under tremendous strain to feed an ever-increasing and mammoth population. Agricultural production poses several global concerns, including sustainability, climate change, and environmental safety, as it strives to increase crop yields. With nanoparticles, agricultural production can be increased sustainably while adverse effects can be minimized. According to estimates, nearly a third of the world's food production is lost annually [7]. Nano-based agrochemicals can improve agricultural practices and agriculture. As nanomaterials are small in size, have a high surface-to-volume ratio, and possess a variety of optical properties, they are ideal candidates for nutritional improvement, plant protection, and farm management practices since they can revolutionize crop production [8] (Fig. 2). Nanotechnology has attracted the attention of several researchers. Nanotechnology will enable the controlled and site-specific delivery of active compounds to plants in the next generation of fertilizers and insecticides. A lot of promising agrochemicals have been developed in the last few years. Nanofertilizers promote faster germination, increase plant tolerance to biotic and abiotic challenges, and increase plant growth while minimizing environmental impact, according to [9].

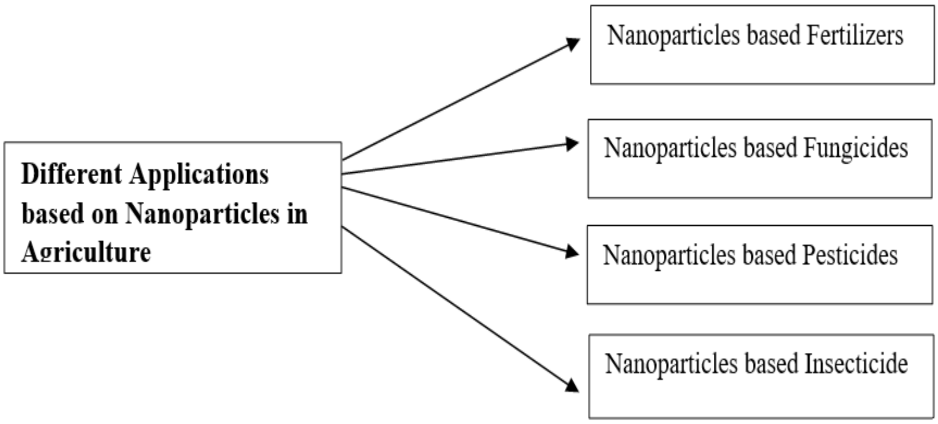

Fig. 2: Applications of Nanoparticles in Agriculture for pest management and crop production

Nanoparticle-based fertilizers- Using too much chemical fertilizer to boost yield reduces soil fertility, contaminates land and water, and poses health risks. It is anticipated that additional fertilizer applications will help meet the challenge of the rising demand for food. Advances in nanotechnology can limit the need for chemical fertilizers and their harmful consequences on the environment and human health. Based on how they are made, there are three basic categories for nano fertilizers. A fertilizer scaled down to the size of nanoparticles is called a nanoscale fertilizer. Traditional fertilizers with nanoscale additives and nanoscale-coated fertilizers are two nanoscale additives [10]. Nanocomposite structures form when nutrients are coated with nanofilms or interposed in nanopores of a carrier material, allowing nutrients to be released in controlled ways [11]. Incorporating fertilizers with nanoparticles has many benefits, like accelerating nutrient uptake, reducing nutrient loss, and improving crop quality and yield. The potential of NPs as fertilizers has been demonstrated in several studies. Iqbal [12] found that foliar application of magnesium and iron NPs increased growth, photosynthesis, and seed weight in *Vigna unguiculata*. Peanut seedling growth was improved by 30% with Ca NPs and humic acids. As NPs based fertilizers are smaller than pores on plant cell walls, they may increase nutrient uptake efficiency (NUE). NP-based fertilizers can be applied to foliage or soil, enhancing nutrient uptake via foliar and root routes.

Nanoparticles-based pesticides- As phytophagous insect pests, insects attack crops in enormous numbers, causing enormous damage [13]. Insecticides are the quickest and cheapest way to control these pests. Various issues have arisen due to the careless use of these synthetic chemicals, including negative impacts on humans, domestic animals, pollinating insects, the environment, and the introduction of these chemicals directly or indirectly into our ecosystems. By using nanotechnology, manufacturers can also manipulate

ISSN (O): 2581-8740 | ISSN (P): 2581-8732
Choudhary *et al*., 2023
DOI: 10.21276/SSR-IIJLS.2023.9.3.3

the properties of carriers so that active ingredients are released meticulously without harming non-target insects or other organisms. A thin-walled shell is used as a protective layer in nano-encapsulation techniques to protect active compounds of pesticides [14]. Using silica nanoparticles (SiNPs) against *Sitophilus oryzae* has shown promising results [15]. Rastogi *et al.* [16] show that SiO_2 NPs cause digestive tract impairment or integument surface expansion in *Callosobruchus maculatus*. There have also been reports of insecticidal properties of Ag and Ag-Zn nanoparticles against *Aphis nerii* [17].

Nanoparticles-based fungicides- There is a significant loss of crops due to fungal diseases attacking field crops. In the case of some major crops, the loss may be as high as 70% resulting in significant economic and yield losses [18]. Despite the availability of conventional fungicides, they threaten biodiversity due to their non-specific nature. As a result, an alternative solution that is specific or precise is necessary to address the issue of fungal diseases [19]. In this area, NPs have shown promising results. Rao and Paria [20] reported that Ag ions and AgNPs have antifungal properties. According to Wakeil *et al.* [21], sulfur nanoparticles are efficient nano-pesticides against *Fusarium solani* and *Venturia inaequalis*. CuNPs and AgNPs have been shown by Ouda [22] to have antifungal effects against *Alternaria alternata* and *Botrytis cinerea*. Moreover, *Rhizopus stolonifer, Alternaria alternative, Fusarium oxysporum*, and *Mucor plumbeus* were all resistant to the antifungal effects of ZnO and MgO nanoparticles.

In addition to ensuring food security, nanotechnology also benefits the environment, the economy, and ecology by reducing the frequency with which pesticides and fertilizers are applied, lowering their environmental impact, minimizing their effects on non-target organisms, and increasing agricultural output. Since metals and nonmetals used to manufacture nanomaterials have the potential may be harmful to humans, plants, and the environment. In typical synthesis techniques, NPs are reduced using chemical compounds and organic solvents, which can be hazardous to the environment. It is necessary to find a method of producing nanomaterials that is both affordable and kind to the environment while keeping their versatility. Leading the charge is environmentally friendly-nanoparticle synthesis. Environmentally friendly, energy-efficient, and lowering the risk of execution and other health issues, the green synthesis of nanoparticles uses bacteria, algae, plant extracts, fungi, and other biomolecules [23]. In green nanotechnology, nanomaterials can reduce toxicity, chemical fertilizers, and pesticides currently essential to sustain agricultural food production and prevent unwanted and harmful by-products.

Future Perspectives- Nanotechnology has had a significant impact on the healthcare industry. Material design in nanomedicine has advanced significantly during the last 20 years. Clinical needs-driven research, based on suggestions from clinical specialists, is necessary for the field's continued development. We will be able to create resources that address clinical requirements. Despite the numerous developments in this area, much work still must be done because of the enormous potential of this nanotechnology-based therapy. Nanomedicine will need to create low-cost diagnostics for microbial infections, genetic predisposition, and illness early detection in the future. Patients will receive treatments or therapies with less intrusion and tailored care. The numerous studies in the review demonstrate a strong belief that trimetallic nanoparticles and nanoparticles based on biopesticide formulations have a promising future and the potential to create safer and more efficient bio-pesticide formulations to control pests, bringing about some early changes in the industry. However, due to the latent toxicity of nanoparticles, more study is needed to determine how the substance affects people and the environment. Plants or plant extracts can be used to create trimetallic nanomaterials. Shape and dimension changes can be made by modifying synthesis techniques, lowering the risk of using them. To make pest management more environmentally friendly, green technology-based nanoparticle formulations must be improved.

CONCLUSIONS

In agriculture and health care, nanotechnology offers a lot of potential. Many types of research proving various uses in agriculture and medicine have exploded in recent years. Without question, nanotechnology is bringing previously unthinkable phenomena into reality. Although the applications are not currently financially viable, they could transform agriculture, lessen the damaging effects

ISSN (O): 2581-8740 | ISSN (P): 2581-8732
Choudhary *et al*., 2023
DOI: 10.21276/SSR-IIJLS.2023.9.3.3

of modern agriculture on the environment, and enhance crop yields. This technology must overcome difficulties like increasing production scale and bringing goods to market while cutting costs and time. Several safety issues must be resolved before nanotechnology can be widely accepted in medicine and agriculture. It has yet to be confirmed whether highly reactive nanomaterial can act as transporters for poisons to enter cells or if they build up non-soluble nanoparticles. To find out how nanomaterial affects living systems, more research is needed. Only risk assessment studies can answer safety questions and ensure a product is safe before approval. To the benefits of nanotechnology, risk assessment studies must keep pace with advancement.

ACKNOWLEDGMENTS

The authors acknowledge the facilities provided by Head and Principal Investigator RUSA Thematic Project number 5 Department of Zoology, University of Rajasthan, Jaipur, India.

CONTRIBUTION OF AUTHORS

Research concept: Sandeep Kumar Choudhary, Ram Niwas Jangir, Shashi Meena, Rahul Tiwari

Research Design: Sandeep Kumar Choudhary, Pratap Chand Mali

Supervision: Pratap Chand Mali

Literature search: Sandeep Kumar Choudhary, Ram Niwas Jangir, Shashi Meena, Rahul Tiwari

Writing article: Ashwini Sajjan

Critical review: Pratap Chand Mali

Article editing: Sandeep Kumar Choudhary, Ram Niwas Jangir, Shashi Meena, Rahul Tiwari

Final Approval: Pratap Chand Mali

REFERENCES

[1] Taniguchi N, Arakawa C, Kobayashi T. On the basic concept of nanotechnology. Proceedings of the International Conference on Production Engineering; Tokyo, Japan, 1974; 26-29.

[2] Laurent S, Forge D, Marc Port M, Roch A, et al. Magnetic iron oxide nanoparticles: synthesis, stabilization, vectorization, physicochemical characterizations, and biological applications. Chem Rev., 2008; 108(6), 2064–110.

[3] Khan I, Saeed K, Khan I. Nanoparticles: Properties, applications and toxicities. Arabian J Chem., 2019; 12 (7): 908-931

[4] Shang Y, Hasan K, Ahammed GJ, Li M, et al. Applications-of-nanotechnology-in-p (1) Mol., 2019; 24: 2558.

[5] Lee YH, Cheng FY, Chiu HW, Tsai JC, Fang CY, et al. Cytotoxicity, oxidative stress, apoptosis and autophagic effects of silver nanoparticles in mouse embryonic fibroblasts. Biomaterials, 2014; 35: 4706-15.

[6] Rajoria S, Rani S, Chaudhari D, Jain S, et al. Glycine-poly-L-lactic acid copolymeric nanoparticles for the efficient delivery of bortezomib. Pharma Res, 2019; 36: 160.

[7] Baker S, Volova T, Prudnikova SV, Satish S, Prasad MN. Nanoagroparticles emerging trends and future prospects in modern agriculture system. Environ Toxicol Pharmacol, 2017; 53: 10-17.

[8] Khot LR, Sankaran S, Maja JM, Ehsani R, and Schuster EW. Applications of nanomaterials in agricultural production and crop protection: A review. Crop Protection 2012; 35, 64–70.

[9] Gottschalk F, Lassen C, Kjoelholt J, Christensen F, et al. Modeling flows and concentrations of nine engineered nanomaterials in the Danish environment. J Environ Res Public Health, 2015; 12(5): 5581–602.

[10] Mastronardi E, Tsai P, Zhang X, Monreal C, et al. Strategic role of nanotechnology in fertilizers: potential and limitations. Berlin, Germany: Springer, 2015; 25-67.

[11] Tarafder C, Daizy M, Alam MM, Ali MR, Islam MJ, et al. Formulation of a hybrid nano fertilizer for slow and sustainable release of micronutrients. ACS Omega, 2020; 5: 23960–66.

[12] Iqbal MA. Editor Nano-fertilizers for sustainable crop production under changing climate: a global perspective," in Sustainable Crop Production (London, UK: Intech Open), 2019.

[13] Gahukar RT. Mushroom Pest and Disease Management Using Plant-Derived Products in the Tropics: A Review. Int J Vegetable Sci., 2014; 20(1): 78–88.

[14] Gogos A, Knauer K, and Bucheli TD. Nanomaterials in plant protection and fertilization: Current state, foreseen applications, and research priorities. J Agri Food Chem., 2012; 60(39): 9781-92.

ISSN (O): 2581-8740 | ISSN (P): 2581-8732
Choudhary *et al*., 2023
DOI: 10.21276/SSR-IIJLS.2023.9.3.3

[15]Debnath N, Das S, Seth D, Chandra R, Bhattacharya SC, et al. Entomotoxic effect of silica nanoparticles against Sitophilus oryzae (L.). J Pest Sci., 2011; 84(1): 99–105.

[16]Rastogi A, Tripathi DK, Yadav S, Chauhan DK, Zivcak M, et al. Application of silicon nanoparticles in agriculture. 3 Biotech., 2019; 9(3): 1–11.

[17]Rouhani M, Amin SM, Kalantari S. Insecticide effect of silver and zinc nanoparticles against Aphis nerii Boyer of fonscolombe (Hemiptera: Aphididae). Chilean J Agricultural Res., 2012; 72(4): 590–94.

[18]Godfray HC, Mason-D'Croz D, Robinson S. Food system consequences of a fungal disease epidemic in a major crop. Philos Trans R Soc Lond B Biol Sci., 2016; 371:20150467. doi: 10.1098/rstb.2015.0467.

[19]Patel N, Desai P, Patel N, Jha A, Gautam HK. Agronanotechnology for plant fungal disease management: a review. Int J Curr Microbiol App Sci., 2014; 3: 71–84.

[20]Rao KJ, Paria S. Use of Sulfur Nanoparticles as Green Pesticide on Fusarium solani and Venturia inaequalis Phytopathogens. RSC Adv., 2013; 3. doi: 10.1039/C3RA40500A.

[21]Wakeil NE, Alkahtani S, Gaafar N. Is nanotechnology a promising field for insect pest control in IPM programs? In New Pesticides and Soil Sensors. Elsevier Inc. 2017; doi: 10.1016/B978-0-12-804299-1/00008-4.

[22]Ouda SM. Antifungal activity of silver and copper nanoparticles on two plant pathogens, Alternaria alternata and Botrytis cinerea. Res J Microbiol., 2014; 9: 34–42.

[23]Shafey AME. Green synthesis of metal and metal oxide nanoparticles from plant leaf extracts and their applications: A review. Green Processing Synthesis, 2020; 9(1): 304–39.