Agri Articles
(e-Magazine for Agricultural Articles)
Volume: 03, Issue: 05 (SEP-OCT, 2023)
Available online at http://www.agriarticles.com

Nanotechnology: A Boon to Agriculture

(*Taranjeet Kaur)
Department of Biochemistry, College of Basic Sciences and Humanities, Chaudhary Charan Singh Haryana Agricultural University, Hisar, Haryana, 125004, India
*Corresponding Author's email: kaur.taran0895@gmail.com

Abstract
Food shortages are a challenge that many developing nations are suffering as a result of the global population expansion. The agricultural industry could potentially be completely transformed by nanotechnology. The potential uses of nanotechnology in agriculture, from reduced input requirements to improved food quality, can greatly increase agricultural yield. With innovative technologies like nano-herbicides for efficacious weed management, nano-pesticides for efficacious pest management, nano materials as weapons for phyto-pathogens, nano-fertilizers, nano seed priming, nanomaterials for heavy metal removal, crop improvement; nanotechnology can support the agriculture industry.

Introduction
Agricultural practises have had a significant impact on human ecological success, and over 60% of the world's population still depends on agriculture for livelihood. Low nutrient-use-efficiency, lack of both macro and micronutrients, climate change, low productivity, decreased availability of water and agricultural lands, and environmental issues like rising pesticide residue levels are just a few of the many regional and global challenges that the agricultural industry is currently facing. The expanding food demand at a pace of 4%, which is necessary to support a 9 billion-person global population by 2050, exacerbates these restrictions even further. The fields of pharmaceutics, information technology, textiles, and health care have all benefited greatly from nanotechnology since its birth. Regretfully, the agricultural food industry has just recently been pushed to employ nanotechnology. The agricultural industry has benefited greatly from nanotechnology, which may be generally divided into tools like, nano-herbicides for efficacious weed management, nano-pesticides for efficacious pest management, nano materials as weapons for phyto-pathogens, nano-fertilizers, remove contamination of heavy metal it can support the agriculture industry. The use of seed nano-priming in agriculture can improve the quality of seeds and increase resistance against stress conditions.

Nanotechnology in agriculture sector
Development of nano-herbicides for efficacious weed management: Nowadays, the majority of herbicides on the market are mostly efficient in preventing or destroying the above-ground portions of weeds; sadly, this fails to limit the deep-ground weeds, such as tubers, bulbs or rhizomes, from acting as new weed sources the following season. Herbicide efficaciousness can be enhanced by nanotechnological intervention by specifically targeting the receptors in the roots and ground parts of weeds. These nanoherbicides are expected to create new entrance and translocation channels to different parts of the rhizome, preventing glucolysis in the root system. Nanoherbicides have been made using a variety of

nanomaterials, including as inorganic, polymeric, and agro-industrial waste-based nanoparticles. Polymeric nanoparticles in form of nanospheres or nanocapsules have been used to encapsulate a variety of chemical herbicides. Compact size, specific surface area, and regulated release of organic chemicals and metal ions in the field are some of the unique features of nano-enabled herbicide. Nanoherbicides have shown enhanced dispersion, adhesion, and prolonged contact time on the leaves in addition to their capacity to control the release of active compounds (Forini et al. 2022).

Development of nano-pesticides for efficacious pest management: To control pests and increase crop yield and quality, chemical substances known as pesticides are employed. Chemical pesticides' limited specificity, high toxicity, and non-biodegradability are their primary drawbacks. The active component of pesticide may be broken down by a number of environmental variables.. Pesticide concentrations that are regularly at or above parts per billion or parts per trillion in the environment, food supply, and body tissues are considered potential dangers. The purpose of choosing nanopesticide is to mitigate the various issues caused by pesticide misuse and to potentially reduce the amount of chemicals released into the environment. Researchers from all around the world have been working tirelessly in recent years to formulate pesticides with more targeted effects through the use of nanotechnology. By manipulating the outer shell of the nanocapsule to release the active ingredient gradually and in a regulated manner, nanoencapsulation of pesticides is useful as it prevents unnecessary run-off of undesirable pesticide and delivers a low dose over an extended period of time. The use of nanopesticide formulations can transform the management of diseases, and insects in crops by increasing their water solubility, bioavailability, and resistance to environmental degradation (Chaud et al. 2021; Chhipa 2017)

Nano materials as weapons for phytopathogens: The main causes of plant diseases include nematodes, fungus, viruses, and bacteria. Approximately 10–40% of food crop losses in terms of quality and production are attributed to these phytopathogens. Since nanoparticles (NPs) contain inherent antibacterial action, they have been recognised as a novel way to address this issue. The possible modes of action of these metal nanoparticles includes excessive generation of reactive oxygen species inside microbes, disruption of vital enzymes in respiratory chain via damaging microbial plasma membranes, accumulation of metal ions in microbial membranes, electrostatic attraction between metal nanoparticles and microbial cells which disrupt metabolic activities, and inhibition of microbial proteins/enzymes by increased production of H_2O_2.

Agriculture is severely negatively impacted by plant viruses, therefore controlling viral infections requires significant effort. Metal nanoparticles have been shown to have anti-viral properties in plants. They disrupt viral replication through various means, render viruses inactive, and trigger the activation of defence mechanisms in plants, which in turn leads to immunity and growth response that involves the participation of the antioxidant system, resistance genes, and plant hormones (Vargas-Hernandez et al. 2020).

Phytopathogenic fungi are one type of pathogen that causes a wide range of diseases in agriculture. Various nanomaterials are thought to be a viable substitute for controlling phytopathogenic fungi since they have demonstrated good antifungal activity. Their antifungal effectiveness depends on a number of variables, including the nanoparticles' composition, size, shape, distribution, crystallinity, agglomeration, and surface chemistry. The possible mechanisms of antifungal activity of metal nanoparticles includes binding of ions released by nanoparticles to certain protein groups which affect the function of essential membrane proteins and interfere with cell permeability, inhibition of the germination of the conidia and suppress their development, disruption of electron transport, protein oxidation, and alteration of membrane potential, by affecting the potential of the mitochondrial membrane by increasing the levels of transcription of genes in response to oxidative stress,

ions of the nanoparticles have a genotoxic effect that destroys DNA, therefore causing cell death (Cruz-Luna et al. 2021)

Nano-fertilizer- Novel delivery system of nutrients: Supplementing vital nutrients is usually necessary to increase crop production and soil fertility. However, precise fertiliser management is considered to be one of the most important prerequisites for sustainable agricultural development. Utilising engineered nanomaterials in the context of sustainable agriculture has demonstrated an entirely new method of food production that may be able to mitigate the unpredictability of the agricultural sector with limited resources. Nanomaterials are nano-fertilizers, are in charge of giving developing plants one or more types of nutrients to promote and enhance growth as well as increase productivity.

The three types of nanofertilizer—macro-, micro-, and nanoparticulate—are based on the nutrients that plants require. When compared to traditional fertilisers, a macronutrient nanofertilizer with a high volume-to-surface ratio is more efficient and reduces the amount. Micronutrients in nanoform have been shown to significantly enhance plant growth and nutrition quality by increasing their bioavailability to plants. Nanofertilizers, which are specifically formulated to control nutrient delivery based on crop requirements while reducing differential losses, hold great promise. Conventional nitrogen fertilisers, for instance, cause significant losses of up to 50–70% from the soil due to evaporation, leaching, or even degradation . This eventually lowers the fertilizer's effectiveness and raises the cost of production. Conversely, nitrogenous fertiliser nanoformulations coordinate the release of fertilizer-N to coincide with crop absorption requirements. In light of this, nanoformulations shield nutrients from unfavourable losses by direct crop internalisation, thus preventing nutrient interactions with soil, water, air, and microbes (Shang et al. 2019)

Nano seed priming: The quality of seeds determines the productivity of any crop. The in vitro seed germination % was, for the most part, well examined before being given to farmers; sadly, the anticipated outcomes were seldom ever replicated in the field. Smart seed germination processes powered by technology are therefore desperately needed. The application of nano-priming to seeds can help protect them while they are being stored, enhance germination, synchronise germination, and promote plant growth. It can also help crops become more resilient to biotic and abiotic stress conditions, thereby lowering the amount of pesticides and fertilisers needed. In addition to directly combating infections, nanoparticles can modify a plant's or seed's metabolism, which can improve the innate immune system, alter the synthesis of hormones, and increase the plant's resistance to abiotic and biotic stressors. The absorption of nanoparticles under seed coat can raise the amount of active gibberellins, stimulate the generation of reactive oxygen species (ROS), and mobilise stored proteins. Moreover, the way that nanoparticles increase the seeds' absorption of water might put them under enough stress to initiate germination, which boosts the activity of the enzymes involved in stages I and II of the process. Since these systems are able to maintain ROS levels in the ideal range made up by the oxidative window that promotes seed germination, seed nano-priming has been demonstrated to boost germination (do Espirito Santo Pereira et al. 2021)

Nanomaterials for heavy metal removal: One of the main things limiting agricultural productivity and endangering food security is heavy metal pollution. Nanoparticles employ a number of tactics to help plants cope with severe metal stress. In addition to raising the pH of the soil, nanoparticles can adsorb heavy metal, reducing its mobility and bioavailability. By controlling the heavy metal transport genes, they can strengthen a plant's defences. NPs immediately scavenge ROS, boost the synthesis of protective agents, and strengthen the plant defence system, all of which increase nutrition and plant development (Zhou et al. 2020).

Nanotechnology for crop improvement: To address the growing demand for plant-derived products, plant breeders' top priority right now is improving crops. Agrobacterium-mediated

transformation, microinjection, microprojectile bombardment, and viral vectors for gene delivery are the techniques utilised to genetically modify plants. With an effectiveness of only 0.01–20%, these systems are only useful for dicotyledonous plants. However, the merging of nanotechnology and biotechnology facilitates progress in this area. These days, NPs are employed to create effective gene transformation vehicles, and nanobiotechnology techniques are anticipated to offer fresh avenues for the whole substitution of one species' genetic material with another. Consequently, via the desirable alteration of plants, applications of nanobiotechnology may greatly help to fulfil the future need for plant-derived goods (Acharya and Pal 2020).

Conclusion

Nanotechnology is the next revolutionary technology in agriculture which can provide sustainable tools to conventional farming with all its recent advancements.

References

1. Acharya, A., and Pal, P.K. (2020). Agriculture nanotechnology: Translating research outcome to field applications by influencing environmental sustainability. *NanoImpact*, **19**: 100232.
2. Chaud, M., Souto, E.B., Zielinska, A., Severino, P., Batain, F., Oliveira-Junior, J. and Alves, T. (2021). Nanopesticides in agriculture: Benefits and challenge in agricultural productivity, toxicological risks to human health and environment. *Toxics*, **9**(6): 131.
3. Chhipa, H. (2017). Nanofertilizers and nanopesticides for agriculture. *Environmental chemistry letters*, **15**: 15-22.
4. Cruz-Luna, A.R., Cruz-Martínez, H., Vásquez-López, A. and Medina, D. I. (2021). Metal nanoparticles as novel antifungal agents for sustainable agriculture: Current advances and future directions. *Journal of Fungi* **7**(12), 1033.
5. do Espirito Santo Pereira, A., Caixeta Oliveira, H., Fernandes Fraceto, L. and Santaella, C. (2021). Nanotechnology potential in seed priming for sustainable agriculture. *Nanomaterials*, **11**(2): 267.
6. Forini, M.M., Pontes, M.S., Antunes, D.R., de Lima, P.H., Santos, J.S., Santiago, E.F. and Grillo, R. (2022). Nano-enabled weed management in agriculture: From strategic design to enhanced herbicidal activity. *Plant Nano Biology*, 100008.
7. Shang, Y., Hasan, M.K., Ahammed, G.J., Li, M., Yin, H. and Zhou, J. (2019). Applications of nanotechnology in plant growth and crop protection: a review. *Molecules*, **24**(14): 2558.
8. Vargas-Hernandez, M., Macias-Bobadilla, I., Guevara-Gonzalez, R.G., Rico-Garcia, E., Ocampo-Velazquez, R.V., Avila-Juarez, L. and Torres-Pacheco, I. (2020). Nanoparticles as potential antivirals in agriculture. *Agriculture*, **10**(10): 444.
9. Zhou, P., Adeel, M., Shakoor, N., Guo, M., Hao, Y., Azeem, I., Li, M., Liu, M. and Rui, Y. (2020). Application of nanoparticles alleviates heavy metals stress and promotes plant growth: An overview. *Nanomaterials*, **11**(1):26.