NANOPARTICLES – A BOON TO AGRICULTURAL AND HORTICULTURAL CROPS

Abstract

Understanding and modifying matter at scales measurable in nanometres is called nanotechnology (1-100 nm). Unique physical and chemical characteristics, such as face area, severance size, flyspeck shape, and reactivity, define nanoparticles (Bandala and Berli, 2018). When delivered by the epidermal foliar route, Li et al. discovered the presence of Ag-NPs with sizes ranging from 24.8 to 38.6 nm within lettuce leaves. Strawberry plants that were sprayed with Se-NPs enhanced their salt tolerance and yield. Numerous variables, including the donor plant, the age and kind of the explant, the culture media, and growth regulators, all affect commercial in vitro propagation (Rai et al., 2022). According to reports, CeO2 accumulates and translocate to the aerial and edible tissues of horticulture crops with little to no harm (Majumdar et al., 2016). TiO2 nanoparticles have a strong antimicrobial impact. Because of their antibacterial properties, NPs are frequently utilised in disinfection processes. Se-NPs were applied as a foliar spray to strawberry plants to improve their tolerance to salt and yield. This improvement was attributed to Se-NPs' capacity to shield photosynthetic pigments. The same treatment reduced fruit breaking in pomegranates brought on by drought stress as compared to a non-NF treatment. Due to their numerous inventive delivery techniques, nanoherbicides can function as intelligent herbicides and are typically safe. Compared to current techniques and herbicide formulations, they are more stable and long-lasting. More study is needed before they are applied in commercial agriculture. Nanomaterials can be used in a variety of overlapping ways in food packaging systems. Grey nanoparticles (Ag-NPs) can be used as antimicrobial moderator which prevents the action to microbes. Compared to current techniques and herbicide formulations, they are more stable.

Keywords: Nano particles; smart herbicides; stress; crop nutrition; crop management.

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I. INTRODUCTION

Understanding and modifying matter at scales measurable in nanometres (1-100 nm) at least in one dimension is known as nanotechnology. At the nanoscale, the patches' face area is remarkably enormous compared to their diminutive size, which can make them remarkably reactive. The abecedarian packages of the matter at the nanoscale may differ from that of the corresponding bulk material due to their incredibly small size and strong reactivity. These new packets could aid in the creation of ground-breaking technologies that operate in several industries. When dealing with nanoparticles, one of the first and most obvious queries is, "Why are nanoparticles so fascinating? Why deal with these difficult-to-manage and-synthesize ultra- small structures, especially when contrasted to their macroscopic counterparts?. These nanoparticles' distinctive packages contain the solution. The word "nano" is derived from a Greek word that means "dwarf." Unique physical and chemical characteristics, such as face area, severance size, flyspeck shape, and reactivity, define nanoparticles (NPs). The fierce actions of NPs in agricultural fields have earned them the nickname "magic pellets." The use of nanoparticles as nano fertilizers, nano-fungicides, and dressings can help crops produce more, fight diseases caused by excessive chemical use, and be more resilient to biotic stress. They control factory growth and up the metabolic effort. Depending on the type and level of care given, NPs may have a positive or harmful impact on factory-grown species.

II. SYSTEMIC APPROACH FOR SELECTIVITY

1. **Size dependent uptake of NPs:** Given that different barriers contained inside the plants are in the micrometre (mm) to nanoscale range, size of the NPs must be taken into consideration as a critical parameter to research uptake in plants (nm). For instance, the cuticle membrane's constituent cells make up the foliar epidermis. The epidermis is made up of stomata that have two guard cells and form a severance that is between 3 and 12 metres broad and 10 and 30 metres long when the gas exchange aperture is open. Because of these stomatal holes, NPs can move through the stores. Also, the saturation parcels mainly differ for the cuticle subcaste on the epidermis and trichrome of the stomata. The cuticle subcaste, on the other hand, presents in a more significant quantum on the splint epidermis with a size rejection limit in the nm range (Wang, P. *et al.*, 2016). When delivered via the foliar method, Li *et al*. discovered the presence of AgNPs with a size range of 24.8–38.6 nm within lettuce leaves. Additionally, they demonstrated the in-planta transformation of AgNO3 when combined with AgNPs, which further clarifies the biotransformation miracle (Li, W.Q. *et al*., 2020). It's crucial to celebrate the route that NPs take after entering the stores because it provides a general notion of where they might assemble. NPs move up and down a factory using the apoplast and symplast, two significant routes. The apo plastic pathway permits influx through the extracellular gaps involving the cell walls of bordering cells and xylem arteries, whereas the symplastic pathway allows movement through the cytoplasm of conterminous cells (Roberts and Oparka, 2003). Through the passage plasmodesmata, which act as a cytoplasmic ground to facilitate flyspeck migration between adjacent cells, the movement from cell to cell occurs. They are surrounded by 3-nm patches that are between 20 and 50 nm in size (Dietz and Herth, 2011).

2. **Surface charge-dependent uptake of NPs:** With regard to their intake, immersion, and

trafficking inside businesses, NPs have a great deal of freedom. The face receptors, transporters, and particular membrane proteins are modified as a result of the NMs' physicochemical commerce with the shops under their energy and face charge. Compared to their immaculate counterparts, NPs with varying face charges still have the ability to discriminate between aggregation and face packages. The cell wall, a naturally occurring membrane found inside the leaves, has elements that are both hydrophobic and hydrophilic as well as an unstable distribution of fixed negative charges. The uptake of appreciatively charged NPs in the apkins is therefore favourably influenced by the negatively charged cell wall, which provides one reason. The factory cell walls' negative charges serve as the ion exchange's face, perhaps promoting cationic NP penetration over anionic NP penetration. Contrary to this, negatively charged NPs have significantly higher transport efficiency. Zhu *et al*. demonstrate highly advanced adsorption of appreciatively charged NPs at root shells, which provides an explanation for the face charge-dependent absorption and transportation of AuNPs. However, it was shown that the internalisation and translocation rates of negatively charged NPs were advanced (Zhu *et al*., 2012). In this environment, negatively charged CeO2 NPs showed limited root accumulation but progressed shoot internalisation, significantly by prostrating electrostatic aversion. In contrast, positively charged CeO NPs with a positive charge explosively adsorbed onto the root shells (negatively charged) (Liu *et al*., 2019).

III. APPLICATION OF NANOPARTICLES IN HORTICULTURAL CROPS

Nanomaterials (NM) are useful for germination and growth in manufacturing facilities. The germination of seeds and the expansion of factories can both be controlled by carbon nanotubes. Increased development and vigour depend on NMs' capacity to penetrate the tough seed covering and permit water importation. Additionally, nanotechnology-assisted seed priming is a potential tactic that, before sowing, further confirms the possibility of high-yield, high-value crops. By interacting with chloroplasts, NPs formed of mesoporous silica (MSNs) can improve photosynthesis, resulting in improved seed germination, higher total protein, and chlorophyll content. Silica plays an essential part in furnishing nutrition as its insufficiency accordingly makes shops weaker and largely susceptible to biotic and abiotic stress.

1. **NPs mitigate abiotic stress response:** NPs not only support the expansion of businesses but also protect them from abiotic stress (Salem *et al*., 2021). Because of its high face area and small size, the NP attracts poisonous essence, which reduces its vacuity. Failure, salinity, alkalinity, temperature fluctuations, mineral and essence toxins, and failure are examples of abiotic stress. NPs can act as nano-enzymes to scavenge against oxidative stress, simulating the activity of antioxidant enzymes (Sharifi *et al*., 2020). According to Zahedi *et al*., Se-NPs (10 and 20 mg l^{-1}) applied as a foliar spray to strawberry plants increased their tolerance to salinity and yield. This was attributed to their capacity to shield photosynthetic pigments (12.19 percent higher chlorophyll a and 40.47 percent higher chlorophyll b contents) and 13.63 percent higher free proline levels when compared to the non-NP treatment (Zahedi *et al*. 2019). Spraying Se-NPs on pomegranate reduced fruit cracking brought on by drought stress in comparison to non-NF treatment (Hasan, 2015).

2. **Water management:** For the treatment of surface water, groundwater, and wastewater

contaminated by harmful essence ions, organic and inorganic solutes, and microbes, nanotechnology offers the possibility of novel nanomaterial. Numerous nanomaterials are being researched and developed for use in water purification due to their special ability to combat obstinate contaminants. Pathogens found in water need to be quickly and accurately connected in order to ensure public health. Traditional laboratory testing, however, take a lot of time. Enzyme- based, immunological, or inheritable test-based faster approaches are being developed. Nanofiber membranes and nanobiocides, which seem promising and effective, may help with water filtering.

3. **Seed germination and plant growth:** The germination stage of a plant's life is the first stage; it offers the conditions for a healthy development, optimal growth, and sufficient productivity (Feregrino-Perez *et al*. 2018). CeO_2 nanoparticles, a commonly produced metal oxide nanoparticle, have been shown to accumulate and translocate to aerial and edible tissues of horticulture crops with negligible toxicity and biotransformation (Wang *et al*., 2016a; Xue *et al*., 2016 and Majumdar *et al*., 2016). Studies with CeO_2 nanoparticles (NPs) show a reduction in seed germination in Raphanus sativus L. However, when the exposure time is extended to 15 days, no effect is seen, indicating that CeO_2 NPs only have an impact on the early phases of germination (Corral-Diaz *et al*., 2014). Due to improved water and nutrient uptake and use, the combination of SiO_2 and TiO_2 nanoparticles can hasten the germination and growth of soybean plants (Singh and Rattanpal 2014 and Nair, 2016). Due to improved water and nutrient uptake and use, the combination of SiO_2 and TiO_2 nanoparticles can hasten the germination and growth of soybean plants (Singh and Rattanpal 2014). According to research done by Khodakovskaya *et al*. (2013), the addition of concentrations of 10 to 40 g ml 1 increases germination percentages from 74 to 82 percent in 12 days. This is similar to how adding carbon nanotubes accelerates germination processes in tomato plants. In tomato seeds, carbon nanotubes prevent root elongation and slow down germination, but cucumber and onion seeds are more likely to favour toot elongation (Caas *et al*., 2008).

4. **Micropropagation:** Numerous variables, including the donor plant, the age and kind of the explant, the culture medium, growth regulators, etc., affect the success of commercial in vitro propagation. One of the main issues with micropropagation is the in vitro bacterial and fungal contamination that leads to substantial losses in micro propagated plants at various growth stages. The broad- spectrum antibacterial action of nanoparticles against plant diseases is one of their distinctive qualities that is well known. The most often utilised nanoparticles are those made of metals, including tiny metal oxides like ZnO, TiO_2, and SiO_2 as well as nanoscale gold, silver, and zinc. The peptide substrates' tyrosine residues are dephosphorylated by the nanoparticles, which inhibits signal transduction and prevents the development of bacteria (Mittal *et al*., 2014). Nano Zn and nano ZnO were added to the culture media of banana cultures by Helaly *et al*. (2014), and the result was contamination-free in vitro cultures with no adverse effects on regeneration ability. TiO_2 nanoparticles were shown to be quite successful at reducing microbial contamination in a study by Safavi (2014) that examined the antibacterial effect of TiO_2 nanoparticles on potato tissue culture conditions.

5. **Nano fertilizers:** Currently, agriculture has a wide range of difficulties, including nutrient scarcity, declining crop yields, declining soil organic matter, low water vacuity,

soil nutrient scarcity, decreased land area owing to urbanisation and land decline, and manpower shortages (Godfray *et al*., 2010). Nanoscience and nanotechnology operations are expanding greatly, and new designs are always being presented to provide innovative and appealing accessories for crop product and operation. It's one of the most popular concepts in the growing body of knowledge known as "perfection husbandry," which teaches growers how to exploit diseases and other inputs to their advantage. The unchecked population has pushed the massive output of conventional illnesses to boost crop and food product protection, but this ultimately lowers soil fertility and food quality. These chemical illnesses harm mortal health because they are left untreated, and they exacerbate the suffering of the delicate ecology. Nano diseases are intelligent or environmentally friendly illnesses that have the potential to spread more quickly and lose less nutrients, particularly phosphorus and nitrogen. It provides a gradual, regulated flow of nutrients to the desired place, reducing the terrain's and water bodies' pollution (Dwivedi *et al*., 2016). Nano diseases are those that either provide nutrients to shops or, when administered in smaller amounts, increase the impact of diseases (Rameshaiah *et al*., 2015). By simulating illnesses in nano form, it is possible to promote nutrient uptake, which ultimately reduces nutrient loss, boosts crop quality and yield, and lessens the risk of environmental decline. Additionally, it has been shown that the foliar behaviour of these nano-diseases reduces anxiety in retail environments (Tarafdar *et al*., 2012).

6. **Nano pesticides:** By protecting crops from harmful elements like insects and manufacturing conditions, fungicides are utilised to increase and improve agricultural output and effectiveness (Jamplek and Kralova, 2017). However, it has been established that using fungicides is poisonous and lethal for the environment; most of them are lethal and detrimental to human and animal health. As a result, several fungicides are prohibited by state or international authorities. This comprises a number of important and crucial issues, including the high-attention use of fungicides by magpies that affects the ecosystem, increases bioaccumulation, renders the soil infertile, and destroys its microbiota (Meena *et al*., 2020). To boost agronomic production and effectiveness and lessen the impact on the environment, some factors must be taken into account.

   It is difficult and expensive to combine fungicides that are both effective and safe, but nanotechnology offers a novel and cutting-edge solution (Sasson *et al*., 2007). Drugstores used to be significantly impacted by nanotechnology (medicine delivery). It's encouraging given the recent advancements in the agriculture and food industries. Nanotechnology is not just used to defend factories from pests; it is also used to reduce waste, monitor factory expansion, provide better food quality, and safeguard the rise of global food production (Jampilek and Kralova, 2017 and Mittal *et al*., 2020). Pervious concave silica NPs (PHSNs) containing validamycin (fungicide) serve as an efficient water-responsive fungicide transport structure to treat a variety of conditions (Goswami and Mathur, 2019). Nano-mixes were crucial to the creation of fungicides and might be effective against the numerous pests in crops. Similarly, canvas-loaded NPs were more beneficial for nano-fungicide medicines (96). As a nano fungicide, nano silica is effective.

7. **Nano fungicides:** More than 70% of damage to important crops is caused by fungi, which are also the most prevalent. These circumstances have an impact on society by severely reducing crop productivity and encouraging thrift. Conventional pesticides reduce these losses, but they also harm biodiversity since they target a wide variety of

living things. Therefore, we need to consider alternative strategies to improve the effectiveness of the fungal complaint operation. The creation of NPs as a successful tactic against fungi is one of the trendy approaches. AgNPs are often utilised for disinfection due to their antibacterial properties. Both CuNPs and AgNPs have the ability to inhibit the growth of the fungi *Alternaria alternata* and *Botrytis cinerea* (Ouda, 2014). Against *Alternaria alternate, Rhizopus stolonifer, Fusarium oxysporum*, and *Mucor plumbeus,* ZnO NPs and MgO NPs exhibit antifungal activity (Wani and Shah, 2012 and Al-Dhabaan *et al*., 2018).

8. **Nanoherbicides:** Herbicides that function differently and more successfully than the weed control methods now in use are needed (Adarsh and Thomas, 2019; Adarsh and John, 2021 and Mathew *et al*., 2022). Herbicides created or developed using nanotechnology are a potentially strong candidate. The most significant advantages are greater efficacy and less application. As a result, it can operate "smartly" to manage weeds and is referred to as a "Smart Herbicide". Due to the connection between the contents and the material, it is typically believed that nano- formulations will boost the action of active compounds gradually or specifically. Additionally, they provide a lot of particular surface area, increasing affinity to the target (Shang *et al*., 2019). There are many ways to make nano encapsulated herbicides, including solvent extraction, the indirect approach, the direct method, and spray-drying (Chinnamuthu *et al*, 2017). Nanoherbicides have a unique ability to manage weeds that is not possible with conventional approaches (Adarsh *et al*., 2022 and Mathew *et al*., 2022). In addition to being more accessible and effective than other approaches, it controls weeds by depleting weed seed banks, deteriorating germination inhibitors, depleting food reserves, gradual release, etc. The weed seed bank must be depleted in order to reduce weed incidence. One strategy is to harm the pollen grains in weeds' blooms. To kill seeds rather than seedlings, carbon nanotubes can pierce seed coat fissures and openings (Khodakovskaya *et al*., 2009). Even after a ten-fold dilution (200 g ha^{-1}) using nano capsulated atrazine, *Bidens pilosa* seedling death rates remained high (Preisler *et al*., 2019).

One of the factors contributing to weeds' protracted dormancy is germination inhibitors. By dissolving phenolic chemicals, nanoparticles (NPs) are employed to disrupt dormancy and encourage germination of purple nutsedge tubers (Ravisankar *et al*., 2012). The quantity of food material that weeds have also contributes to their longevity. The weed is compelled to die when its food supply runs out because it has no other means of surviving. Silver nanoparticles were bio-conjugated with -amylase and used to break down the starch found in *Cyperus rotundus* tubers (Viji *et al*., 2016). The usage of carrier materials and nanoformulations results in the formation of zwitterion or charged clusters, which slows the release. Pendimethalin copper-chitosan nanoparticle compositions with controlled release significantly reduced and successfully stopped weed germination (Itodo *et al*., 2017). Compared to its free form, paraquat's release profile from the NP polymeric matrix is delayed (Grillo, 2014).Herbicide residues degraded more quickly when metal ions were coupled with suitable carriers and NPs. Iron nanoparticles had atrazine removal capabilities of 90–98%. (Ali *et al*., 2015). Compared to the usage of free paraquat, the degree of DNA damage in onions was lowered by the association of herbicide with nanoparticles (Grillo *et al*., 2014). Black gram’s plant height was greatly raised after NP herbicides were applied because ZnO NPs were absorbed and affected the plant's growth (Vimalrajiv *et al.*, 2018). Because of their numerous intelligent delivery modes, nanoherbicides can function as smart herbicides. The method can result in sustainable, effective, and efficient weed control, and it is generally safe. Compared to current techniques and herbicide formulations, they are more stable. Before using nanoherbicides in commercial agriculture, additional research is needed in the field of nanoherbicide science.

9. **NPs as a Plant diseases control:** The numerous industrial conditions can be implicitly controlled by Ag and SiNPs. AgNPs, or grey nanoparticles, are an antibacterial moderator that stops germs from acting. When compared to synthetic pesticides, these nanoparticles have a lot of potential for reducing factory runs (). The effective antibacterial agents are ZnO and MgO NPs. As a result, it has been determined that the operation of NPs is a necessary and effective method that is cost- and environmentally-efficient for the control of harmful microorganisms.

10. **Post-harvest management:** Crop losses resulting from manufacturing conditions are typically linear and direct. Crop losses range between 20 and 40 percent of the world's agricultural output and are directly caused by infections and other agents like insects, animals, and weeds. Due of their unique properties and crucial functions in food and animal husbandry, nanomaterials have been proposed and have gained acceptance. The nanotechnology approach is helpful in the field of post-harvest technology of fruits and vegetables for controlling post-harvest conditions, introducing a new invention for packaging flicks, preventing impact of feasts and unsafe shafts, perfecting packaging appearance, and helping for labelling fresh products using the multiple chips (nano biosensors) (Roberto *et al*., 2019). Nanotechnology has been used to create antifungal nanoparticles that can be employed in a variety of products, including fruits and vegetables. Numerous nanomaterials have been created to manage conditions in citrus, grapes, banana, apple, mango, peach, and nectarine and have demonstrated implicit post-harvest functioning.

11. **Packaging of horticultural produce:** Most research in this field has focused on food safety, looking at how it can be used to reduce oxidation, regulate microbial growth, make tampering more visible, and increase convenience for both suppliers and customers. Longer shelf life, safer packaging, improved product traceability, and healthier food would all result from a successful offence. As a result, it is predicted that nanotechnology will become one of the most significant forces for innovation in the food packaging industry. Nanomaterials can be used in a variety of overlapping ways in food packaging systems (Martínez *et al*., 2019). For instance, some immobilised enzymes can function as antibacterial agents, oxygen scavengers, and/or nano sensors (Azeredo *et al*., 2011). A few nano packaging items are now available on the market, and applications of polymer nanocomposites, antimicrobial packaging, and nanocoated films are more advanced.

IV. CONCLUSION

Nanomaterials are a new technology that has attracted interest due to their diverse uses and prospective advantages in terms of improved germination, the delivery of nutrients and pesticides, an extension of the post-harvest shelf life, and the use of efficient sensors for product labelling. These materials are a good option to utilise as a key instrument in sustainable gardening due to their special qualities. Biomaterials can be used as nanoparticles to reduce the toxicity of their effects on the environment and on crops (Siddhardha *et al*., 2020). To avoid ecological risks and achieve sustainability, a thorough understanding of interactions between nanomaterials and biological systems is necessary.

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