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Application of Chitosan Nanoparticles Produced from Shrimp Shell Waste throughout the Agricultural Sector

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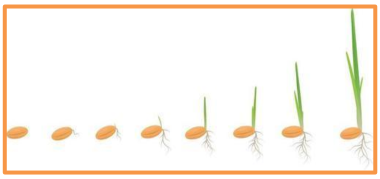
A naturally occurring linear-hetero-biopolymer made up of β (1-4) 2-acetamido-2-deoxy-β-D-glucopyranose (N-acetylglucosamine) and 2-amino-2-deoxy-β-D-glucopyranose (D-glucosamine) units, chitosan is derived from chitin (Badawy and Rabea 2011). Chitosan is essentially a marine polysaccharide that is obtained from the tough outer skeleton of shellfish, such as shrimp, crab, and lobster. Solid particles ranging in size from 1 to 100 nm, are often known as nanoparticles or particulate dispersions. The nanoparticles prepared using chitosan can be called chitosan nanoparticles (Nano-chitosan).Due to its small size, solubility, surface area, and biological characteristics, this material is used in the agriculture sector for plant growth enhancement and increased productivity, as an antimicrobial for plant disease management, as a foliar spray and preservative, for seed treatment and soil application, etc.

1. Growth Promoter - When compared to chitosan (50 µg/mL), nano-chitosan demonstrated a growth-promoting effect at a lower dose (5 µg/mL) (Van *et al.,* 2013). Wheat's growth performance and yield significantly increased when nano-chitosan/NPK fertilizers were applied. The stimulatory impact of chitosan in triggering different metabolic pathways involved in the growth and development of roots and shoots may be the cause of the potential increase in growth indices.Furthermore, increased the concentration of indole-3-acetic acid (IAA) in wheat shoots and roots and made extra amino compounds from chitosan available, which acts as an additional source of nitrogen for plant growth. These actions also induced the expression of auxin-related genes, sped up the biosynthesis and transport of IAA, and decreased the activity of IAA oxidase.

2. Seed Germination - Chitosan nanoparticles (5 mg/mL) were applied to wheat seeds, and the consequence was an increase in the rate of seed germination as well as better seedling growth. This was likely due to the NPs' ability to attach more nutrients, such as phosphorus and nitrogen, to the seed's surface, which increased the seed's surface area. Because of its ability to produce films, chitosan nanoparticles (NPs) can create a semi-permeable layer on the film surface, assisting in preserving the moisture content of plant seeds.

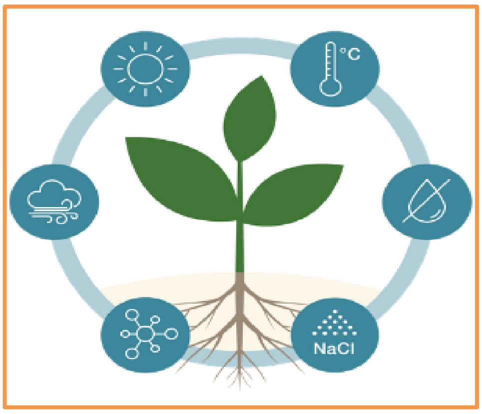


3. Foliar spray - Plants of strawberries that were treated with chitosan topically also showed higher levels of potassium and phosphorus in their leaf tissues. When applied topically to finger millet plants, chitosan nanoparticles (NPs) loaded with zinc were found to dramatically increase the levels of Fe, Zn, Mn, P, Ca, and Mg. Similarly, foliar treatment of NPs loaded with zinc was tested on maize plants grown in either alkaline or zinc-deficient soil.

4. Soil application - To monitor soil conditions in real-time and identify possible issues like nutrient depletion or inadequate watering, farmer fields are being with nano-sensors. A chitosan sensor with nanoparticle modification for heavy metal detection has recently been developed. The combination of chitosan cross-linked with glutaraldehyde and para-magnetic Fe_3O_4 modification serves as the basis for this biosensor. Easy to manufacture, the Fe_3O_4/chitosan nanocomposite film shows good accumulation efficiency for heavy metal (nickel, lead, and arsenic) detection and removal.

5. Delivery of pesticides, herbicides, and fertilizers: In the same way, the role that chitosan in NP formulation has been proposed to play in the effective delivery of fertilizers and other micronutrient compositions is being investigated (Kashyap *et al.*, 2015). For example, bulk NPK formulation and chitosan-polymethacrylic acid-NPK NP formulations were applied to *Triticum aestivum* and compared. It was discovered that the addition of chitosan nanoparticles to the formulation of paraquat herbicide altered the chemical's release profile, suggesting that this approach would be effective in lessening the unfavorable effects of the herbicide. When compared to the control herbicide formulations, the chitosan/tripolyphosphate NPs proved to be more effective when utilized as a paraquat carrier on the maize (*Zea mays*) and mustard crops. Using the cross-linking agent glutaraldehyde (GLA) and tripolyphosphate (TPP), chitosan was utilized to create nanoparticles with the botanical insecticide PONNEEM®, which showed excellent potential for managing *H. armigera*. The weights of *H. armigera* pupae were dramatically reduced by the larvicidal activity of both types of nanoparticles, which also demonstrated antifeedant action.

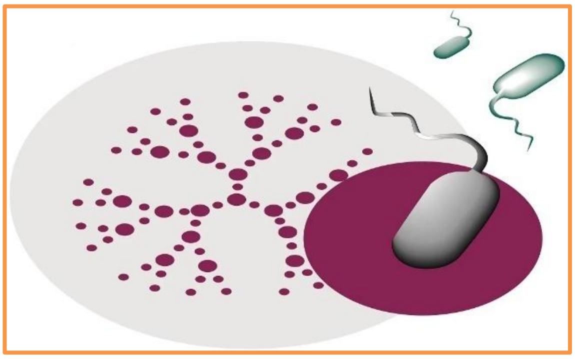
6. Stress resistance - Chitosan nanoparticles applied at a rate of 1% successfully reduced the effects of drought stress in *C. roseus* plants. Proline accumulation was boosted by chitosan nanoparticles, and ascorbate peroxidase and catalase activity were also raised. These effects may have reduced the effects of oxidative stress brought on by dehydration. Furthermore, by thickening the roots and enhancing their capacity to absorb more water, the chitosan coating aids in the plants' development as drought-resistant species. Additionally, there is proof that under low-water conditions like drought, chitosan promotes the synthesis of abscisic acid, which lowers transpiration rates and keeps stomata closed.



7. Post-harvest management- To enhance the postharvest life of tomato cherries and blueberries, quinoa protein/chitosan edible films were improved with the addition of chitosan thymol nanoparticles produced through ionic gelation. The permeability to water vapor was reduced more effectively by films containing chitosan nanoparticles. Because it serves as a mechanical barrier, lowers water evaporation, safeguards against contamination by microbes, is compatible with packed materials, and degrades readily in harsh environments, polymeric chitosan has the potential to be a significant food packaging substitute. Additionally, biodegradable polymeric matrixes that require enhancement in their mechanical and barrier qualities may employ chitosan nanoparticles as a filler ingredient.

8. Fruit and vegetable coating - An alternate technique for extending the shelf life of some fruits and vegetables is an edible coating. Foods can have a longer shelf life by preventing microbial deterioration due to the high antibacterial qualities of chitosan and chitosan-based edible films, which are biodegradable substances. Another fruit that is known to spoil quickly is the banana. Researchers applying chitosan to extend its shelf life revealed that the fruit would ripen more slowly and contain more vitamin C, as well as that the application would not cause weight loss.

9. Antimicrobial agent - Chitosan also inhibitsthe growth of various plant pathogenic bacteria and fungi like *Botrytis cinerea*, *Fusarium oxysporum*, *Micronectriella nivalis*, *Rhizoctonia solani*, *Erwinia carotovora*, *Agrobacterium tumefaciens*, etc. Chitosan can activate some pumps of the plant cells that may secrete anti-pathogenic compounds. The most prevalent proposed antibacterial activity of chitosan nanoparticles is by binding to the negatively charged bacterial cell wall causing disruption of the cell, thus altering the membrane permeability, followed by attachment to DNA replication and subsequently cell death.



Conclusion

Being a naturally occurring biodegradable, ecologically safe, biocompatible, and non-toxic substance, nano-chitosan is a powerful substance of interest. Chitosan in nanotechnology is also an emerging field. The field of chitosan-based nanoparticles is undergoing a revolution, and agricultural applications stand to benefit greatly from its enormous potential. These biobased approaches are beneficial to the environment and contribute to climate resilience and sustainable agriculture.

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