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Use of Chitosan in Modern Agricultural Production

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Agrochemical overuse has significant detrimental effects on ecosystems. A promising strategy to mitigate this issue is the controlled release of agrochemicals through biodegradable particles. Given the highly competitive agricultural sector and increasingly stringent ecological regulations, it is crucial for scientists, researchers and farmers to prioritize both product quality and environmental sustainability. One such biopolymer is chitosan, a linear polysaccharide composed of D-glucosamine and N-acetyl-D-glucosamine units derived from the deacetylation of chitin. Chitosan possesses unique physicochemical properties, making it highly versatile in various biological and biomedical applications. In agriculture, chitosan plays a crucial role in controlling plant diseases and pests, enhancing plant properties and maintaining ecological balance by promoting symbiotic relationships between plants and beneficial soil microorganisms. Additionally, chitosan nanoparticles can act as nanocarriers for conventional agrochemicals, thereby being classified as chitosan-based agro-nano chemicals. The favorable properties of chitosan such as its non-toxicity, biocompatibility, low allergenicity and biodegradability enhance its utility in a wide range of applications. Chitosan is also recognized as a bio-stimulant, promoting plant growth and aiding in the management of biotic and abiotic stressors. Moreover, chitosan demonstrates the ability to chelate heavy metals including lead, copper, mercury, uranium from soil and agricultural effluents, facilitating their removal. This property allows chitosan to be repurposed in irrigation, offering an eco-friendly solution to heavy metal contamination in agricultural environments.

Chitosan in Plant Health

Since the 1980s, the study of chitosan has been shifting from a general sewage treatment agent to plant growth regulator, soil conditioner, seed coating agent, especially in the crop disease management. Chitosan acts as not only an antimicrobial agent but also an effective elicitor of plant systemic acquired resistance to pathogens. Chitosan has been demonstrated to induce plant defenses in cucumber, tomato, chili, strawberry and rose shrubs. Chitosan can activate innate immunity by stimulating hydrogen peroxide production in rice, induce a defense response by nitric oxide (NO) pathways in tobacco, promote the development and drought resistance of coffee, support the synthesis of phytoalexin, impact the jasmonic acid–ethylene (JA/ET) signaling marker in oilseed rape seed and trigger defense-related gene expression. Soil amendment with chitosan has frequently been shown to control Fusarium wilts and gray molds in a number of crops. Besides this, another one of the most important bioactivities of chitosan on plants is stimulation of seed germination in response to abiotic stress. Chitosan easily absorbs to plant surfaces which helps to prolong the contact time between agrochemicals and the target absorptive surface.

Effect of Chitosan on Plant Growth

Chitosan functions as a plant growth promoter in various crops such as beans, radish, gerbera, potato, cabbage soybean and other crops. As a result of plant growth promotion activities, significant yield increases in various vegetable crops. Chitosan has a major influence on the growth rates of shoots, roots, flowering of plants. Significant growth improvements have been found by several studies in radishes, cabbage, soybean sprouts, sweet basil and also in ornamental crops including gerbera and dendrobium orchids by various modes of application such as soil application, pot application and biofertilization. To increase crop yield, a mixture of chitosan and plant-growth-promoting rhizobacteria can be utilized as biofertilizers. It is also utilized in potted freesia cultivation as a biostimulator. Use of chitosan formulation could accelerate the length of root and shoot and yield of various cereal grains. It also promotes the growth of plants such as chili, tomato and cucumber raised in the nursery.

Effect of chitosan in crop protection

In the agriculture sector, chitosan nanoparticles could act as an antimicrobial agent against the crop pathogenic microorganisms like fungi such as *Alternaria solani*, *Pyricularia grisea*, *Fusarium oxysporum* and many insect pests like *Aphis gossypii*, *Helicovera armigera*, *Callosobruchus chinensis* and *Callosobruchus maculatus* etc. The formulations of chitosan nanoparticles have the capability to enhance the plant defense mechanisms by obtaining the defense enzyme functions upon its application. Chitosan alone or in integration with other active agents demonstrates promising perspective as a sustainable choice to the conventional fungicide application against Fusarium wilt and head blight disease in wheat, blast of rice, leaf spot in maize, blast of finger millet. Chitosan nanoparticles are sensitive to the fungi like *Fusarium oxysporum*, *Fusarium solani*, *Aspergillus flavus*, *Aspergillus terreus, Alternaria tenuis* and *Sclerotium rolfsii*. These particles exhibit a more significant percentage of mycelial growth inhibition compared to bulk chitosan. It has been accounted that the smaller size, higher porosity of these chitosan particles make it highly stable, which ultimately affects the tested fungal pathogens.

Types of Chitosan nano particles

- **Conjugated chitosan nanoparticles (ChNPs):** As a new approach, conjugated NPs have been widely concerned by researchers in recent years. It can easily be conjugated with other moieties due to having an amine group. Metals like silver, copper, iron, zinc and nickel are highly compatible to form chitosan metallic nanoparticles and are proved to be non-toxic to the agricultural plant system. Carboxymethyl chitosan (CM) and Magnetic nanocomposite (MN) are drastically used in agriculture production.
- **Polymeric chitosan nanoparticles (ChNPs):** Polymeric ChNPs are most commonly used due to their simplicity to modify its surface and stability. Biopolymeric nano particles have additional advantages such as accessibility from marine or agricultural resources, biodegradability, biocompatibility and non-toxicity. Chitosan nano particles are biodegradable polymers hence these are mainly studied as delivery systems for slow and controlled release of active ingredients, stabilization of biomolecules such as proteins, genetics materials, and peptides.
- **Encapsulated chitosan nanoparticles (ChNPs):**Encapsulation technique is essential for food processing, bioengineering industries and agriculture fields. In recent years, metal encapsulated chitosan has to pay more attention because of their dual activity as a plant protection agent and plant growth promoter. The delivery of ChNPs loaded with nitrogen, phosphorus and potassium applied onto leaf surfaces eventually penetrates the stomata by gas uptake, evading direct interaction with soil systems which significantly provokes the yield variables. To develop an effective nano delivery system, plant growth regulators

may be encapsulated in the chitosan nanocarriers that slowly release the hormones with higher bioavailability.

Methods of application

- **Seed treatment:** Seed treatment is a better and advanced approach as compared to soil amendment. A most recent approach is based upon maintaining the integrity of seed coat and simultaneously reducing water solubility using biodegradable hybrid coats of chitosan for seeds. The strategy of chitosan application in seed treatment is considered as the primary artificial defense activation in plants against the different infectious agents. The biopolymer with a high molecular weight of chitosan applied as a covering film around the seeds can be used as a deliverance system for different products used in plant protection, fertilizers, and plant growth-promoting micronutrients to protect the infection by pathogens.
- **Soil application:** Although chemical-based fertilizers and pesticides have high and immediate impacts on crop yield, they also negatively affect the environment and consumers. Less than 0.1% of agrochemicals are delivered to plant systems, and the rest are washed off into the atmosphere. Chitosan particles are studied for their utilization in agriculture as a soil applicant to manage various fungal and bacterial diseases, as a nano fertilizer and as an efficient delivery system for agrochemicals. There is no significant effect of ChNPs on the soil enzyme activity and microbial population compared to the chemical fertilizers.
- **Foliar application:** Foliar application of Chitosan nano particles is used to increase the growth and production in the plant. These particles get easily absorbed by leaves, penetrate the plant through stomata, travel down into the plant through the phloem and provide nutrient to a different part. The ChNPs increase the nutrient uptake of nitrogen, phosphorous and potassium by 30–45% which impacts in crop growth such as coffee. Foliar application of ChNPs-NPK fertilizer has been reported to improve wheat yield, developed on the two different soils. The foliar application increases the output of the wheat plant and it also reduces the life cycle of the crop and also affects the chemical composition of wheat grains with increased element content such as potassium and phosphorous.

Conclusion

Chitosan, a chitin derivative, is the second most widely distributed abundant natural polymer. Over the last decade, the number of uses of chitosan and its derivatives has significantly increased. The availability of information on biocompatible and biological characteristics of chitosan makes it a potential bioactive substance for agriculture. To date, there is ample evidence to suggest that plants may achieve improved tolerance to a broad range of pathogenic micro-organisms and promote growth and development after the application of chitosan. Future studies may aim at explaining the real target molecule on the cell membrane or even other intracellular targets in case of an antimicrobial mechanism of action. Moreover, further investigations are also required for pathogen resistance mechanisms against this polymer.

References

1. Bandara, S., Carson, H. D.L., Bradford, D. and Kommalapati, R. (2020). Agricultural and biomedical applications of chitosan-based nanomaterials, *Nanomaterials* **10** (10):1903.
2. Divya, K. and Jisha, M.S. (2018). Chitosan nanoparticles preparation and applications. *Environmental Chemistry Letters*, **16**: 101–112.

3. Kusumastuti, Y., Istiani, A., Purnomo, C.W. (2019). Chitosan-based polygon multilayer coating on NPK fertilizer as controlled released fertilizer. *Advances in Materials Science and Engineering*, 2958021.
4. Malerba, M., Cerana, R. (2016). Chitosan effects on plant systems, *International Journal of Molecular Science*, **17** (7):996.