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Nanopesticides

(*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
A concentrated effort must be made to develop novel, eco-friendly, smart nano-pesticides that are resistant to pests, given the detrimental effects of conventional pesticides. To get optimal results, nano-pesticides provide prolonged sustained release kinetics, greater permeability, stability, and solubility over extended periods of time. They also prevent the encapsulated compounds from degrading under unfavourable environmental circumstances.

Keywords: Controlled release, pest control, nano-pesticide

Introduction
The productivity of agriculture drives the Indian economy, and farmers depend on the harvests. A significant source of worry over agricultural spoiling is the abundance of insects and pests that harm crops. Several chemicals have been tried to either kill or hinder the reproduction and feeding habits of insects in order to prevent the countless losses caused by them on agricultural land. In order to increase crop productivity, pesticides are unavoidable in agriculture. More than 90% of pesticides that are employed are lost because of drift, leaching in soil, photolysis, hydrolysis, and microbial activity (Dangi and Verma 2021). Because only 1% of pesticides actually reach the target location, repeated pesticide applications are necessary, increasing costs and polluting the ecosystem in the process. Approximately two million tonnes of insecticides are used annually to manage pests globally. This excessive dependence on chemicals has resulted in a number of issues, including a rise in the number of farmer cases of pesticide poisoning, a decline in pollinator populations, a reduction in soil biodiversity, toxicity to mammals, the emergence of insecticide resistance, the presence of pesticidal residues on marketed fruits and vegetables, and hazards to other non-target organisms in the ecosystem. A lot of time has been put into developing novel pest control techniques through the introduction of creative pest-resistive concepts and cutting-edge technology for pest management, mostly due to the detrimental effects of pesticides.

Therefore, the most effective way to produce a variety of distinct physicochemical qualities may be found by employing advanced technologies like nanotechnology, which works with materials at the nano-scale. In order to effectively protect crops against insect pests and diseases, nano-pesticides have to offer a wide range of benefits (such as increased effectiveness and durability, good dispersion and wettability, ability to biodegrade in the soil and environment, lack of toxicity, and photogenerative nature), as well as a reduced amount of active ingredient with convenient pesticide properties. Without compromising their effectiveness, nano-pesticides are more target-specific and have a lower environmental impact with controlled release of active ingredient along with considerable increase in the stability of the active ingredient used in low concentrations. Therefore, target-specific nano-pesticides ought to assist in lessening the harm done to non-target plants and lowering the quantity discharged into the environment (Kumar et al. 2019).

Classification of nano-pesticides

There are two main categories into which nanopesticides may be divided:

1. Pesticides with coherent nano-scale components; they usually include an active pesticide nano-dispersant emulsion. Pesticide nanoemulsions have several potential benefits over other approaches, including strong surface adherence, high penetrability, and wide range of applicability.
2. Pesticides that have been coated, doped, loaded, or encapsulated by nanomaterials. Pesticide nano-encapsulation has the benefit of allowing for the regulated and gradual release of the active ingredient by modification of the nano-capsule's outer shell. This results in the release of a low dose of active ingredient over an extended period of time and lowers the undesirable run-off of pesticide. Natural polymers including polysaccharides and proteins are typically utilised in nano-encapsulation of nano-pesticides.

The types of pesticides listed above often transports, stores, and controls pesticide exposure in addition to offering many of the possible advantages of traditional pesticides. An additional benefit of nanocarriers for plant protection is the site-targeted distribution and stability of the active component. Likewise, a nanoemulsion of oil or water increases the pesticide's solubility and effectiveness against certain pests. Several varieties of nanopesticides have been produced. Nanoparticles are more efficient than their bulk constituents because of their small size and high surface-to-volume ratio. A broad-spectrum substance that acts against phytopathogens is silver nanoparticle (Shekhar et al. 2021; Bratovcic et al. 2021).

Benefits of nano-pesticides

- Improved leaf adhesion and penetration
- Reduces pesticide application and treatment frequency
- Targeted delivery
- Slow controlled pesticide release
- Decrease the risk of resistance emerging
- Reduces the cost of pest control
- Protect the pesticide against premature degradation
- Enhance the solubility of poor-water soluble pesticide
- Improve pesticide bioavailability
- Improve the stability of formulation
- Reduces environmental pollution risk
- Enhance the uptake of pesticide by target pest
- Lower the risk of organic solvent run-off

Conclusion

In the current agricultural system, where chemical pesticides are the primary means of controlling pests, nanotechnology has significant promise. The best substitute are nano-pesticides, which allow for targeted delivery, controlled release of active components and improve solubility, dispersion, and bioavailability while guarding against premature degradation. The active ingredient's encapsulation boosts its mode of action while lowering their toxicity. Because of their huge surface area, nanoparticles in particular can achieve a high rate of solubility and extensive coverage of plant/leaf surfaces.

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