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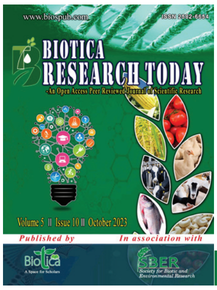

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Nanopesticides: Scope and Utility in Insect Pest Management

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Abstract

Insect pests are the major biotic stress responsible for yield loss in crop plants under field and storage conditions. Chemical pesticides used for the management of these pests result in problems like resistance, resurgence and residue problems due to the poor water solubility, dispersibility and persistency of conventional pesticide formulations. Because of their poor pest control performance, repeated use of insecticides is necessary, which will further enhance the above-mentioned pesticide problems. Nanopesticides having a particle size below 100 nm have advantages over their conventional commercial formulations concerning improved solubility, dispersibility and persistency. The use of nanopesticides will not only avoid the problems associated with pesticide usage but also reduce the cost of plant protection by cutting down the amount of active ingredients required for pest management.

Keywords: Insect pest management, Nanoemulsions, Nanopesticides, Nanotechnology

Introduction

Nanotechnology is one of the emerging cutting-edge technologies having an interdisciplinary approach between material science, physics, chemistry and biology. Nanotechnology has applications in almost all sectors like healthcare, biology, agriculture, energy, electronics, communication, aerospace and defense. The estimated global market of nanotechnology in 2020 was US$ 42.2 Billion, but it is estimated to reach US$ 70.7 Billion before 2026 (Anonymous, 2023), which attracted investors, policymakers, manufacturers and government officials to undertake research and developmental activities in various fields. The realm of nanotechnology lies in the 0.1 to 100 nm size of the particle. This nanometric size is responsible for the magnificent properties of a material mainly owing to their higher surface area to volume ratio. Nanoinsecticides are synthesized by employing innovative techniques of nanotechnology and are aimed to strengthen the efficacy and bring down the environmental contamination with pesticides. Nanoinsecticide formulations are characterized with their ingredients in a nanometer size and consists of organic (polymers) or inorganic (metal oxides) compounds. These nanoformulations can mount up the effects of the formulation applied to the plants because of their distinct properties of decreasing the surface tension which inturn reduces the frequency of insecticides applications due to enhanced efficacy and hence the cost of plant protection can be reduced.

Types of Nanoinsecticides Formulations

The nanoformulations are classified into five different types, *viz*., nanoemulsions, nanosuspensions, nanocapsules, nanoparticles and nanogels. The main aim of the nanoformulations is to enhance the efficacy, controlled release of active ingredient ensuring safety of the products to the environment.

1. Nanoemulsion

Nanoemulsions are isotropous and stable systems and they are transparent (particle size < 200 nm) or milky (particle size ≈ 500 nm) with the mean particle size ranging from 50-1000 nm. Here the oil globules having the hydrophobic portions are made stable with the help of an emulsification agent. Three main components of nanoemulsion are oil, emulsifier, and additives like antioxidants. Based on the dispersant and dispersed medium, the nanoemulsions are classified into oil-in-water (O/W), water-in-oil (W/O), and bi-contentious emulsions.

2. Nanosuspensions

Nanosuspensions are mainly used for powder form of

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insecticides. The powder forms insecticides are not soluble in water (hydrophobic) but are miscible in oil. Hence they have many disadvantages like dust drift, environmental pollution (due to organic solvents used) and poor dissipation which will decrease their pest control performance (Qian and Tao, 2005). By converting powder formulations into their nanosuspensions, the dispersion, stability and biological availability will be augmented.

3. Nanocapsules

In nanocapsules, the outer cover is prepared from an ecofriendly (organic) materials like polymers. This membrane encapsulates the inner most nano-sized core (liquid or powder substance) so as to safeguard the active ingredient from weather factors, controlled active ingredient release and time specific target activity (Ezhilarasi *et al*., 2013). The particle size of the nanocapsule varies between 10 to 1000 nm.

4. Nanoparticles

Nanoparticles have the particle size smallest of all the formulations, *i.e*., 1 to 100 nm. As the particles are very small, they will spread uniformly all over the leaf surface and uniformly cover an entire seed when sprayed under field and used for seed treatment, respectively. The nanoparticles are broadly categorized into two types, *viz*. organic nanoparticles (Examples: micelles, dendrimers and liposomes) and inorganic nanoparticles (Examples: silver, gold and silica nanoparticles). Nanoparticles can be synthgesized either from plant or microbial based. The particle size ranges from 1 to 100 nm.

5. Nanogels

Nanogels are formed by cross-linking the polymer networks (in nanometer size) either by physical or chemical methods (Kabanov and Vinogradov, 2009). These are mainly employed in drug delivery systems as carrier agents for active ingredients.

How do Nanoparticles enter into a Cell?

1. In Plants

The nanoparticles enter into plant cells by a diffusion process. This is aided by pore enlargement or formation of a new pore in the plant cell wall. Here the nanoparticle is being rounded by a cavity-like structure of plasma membrane that facilitates the endocytosis process which paves the way inside the plant cell. Sometimes nanoparticles may enter with the cell with the help of transport or carrier proteins and ion channels in plasma membrane. Specifically when applied on the leaf surface the nanoparticles enter *via* the stomatal openings that lead them to various tissues.

2. In Insects

There are mainly three modes of entry of nanoparticles into insect body, *viz.* by physical contact, through food (ingestion) and through respiration (inhalation). As the particle size is at the nanometer scale, they will easily penetrate the insect exoskeleton and can easily pass through the airways (Anandhi *et al.*, 2020).

Mode of Action of Nanopesticides in Insects

- Silver nanoparticles can bind to sulfur in nucleic acids and phosphorus in proteins resulting in the decreased membrane permeability to the organelles and also causes enzyme denaturation and finally cell death.
- Also, silver nanoparticles can cause changes at the molecular level by upregulating and down-regulating the major insect genes and hence reduce protein synthesis and release of gonadotrophin leading to abnormal growth and reproduction.
- In case of chemical nanopesticides like organophosphates, carbamates, synthetic pyrethroids, avermectins, *etc*. and botanical insecticides like neem, sweet flag rhizome oil, *etc*. the mode of action remains same as that of the active ingredient but the penetration, hydrophilicity and permeability of the nanoformulations will be increased owing to their smaller particle size (10^{-9} m) which further increase the biological activity of the pesticide.

Scope of Nanopesticides in Insect Pest Management

The unscientific use of conventional insecticides resulted in several problems like insecticide resistance, resurgence and residue in grains. There is an increasing level of awareness among people towards comparatively residue-free food. By using nanopesticides, the requirement of active ingredients intended for pest control is considerably reduced and hence the residue problem will be less. Even

Table 1: Nanopesticides used in insect pest management

Sl. No.	Nanopesticides	Target insect
1	Silver nanoparticles	*Callosobruchus maculatus* (Fabricius) and *Trogoderma granarium* Everts
2	Eucalyptus oil nanoemulsion	*Sitophilus oryzae* (L.) and *Tribolium castaneum* (Herbst)
3	Nano-emamectin benzoate	*Spodoptera littoralis* (Boisduval)
4	Silver and Zinc oxide Nanoparticles	*Helicoverpa armigera*
5	Nanoemulsions of malathion, diazinon and chlorpyrifos-methyl	*Spodoptera littoralis* (Boisduval)
6	Nanoemulsions of chlorpyrifos, malathion, cypermethrin, deltamethrin and lambda-cyhalothrin	-
7	Nanoemulsion of neem oil	*Sitophilus oryzae* and *Tribolium castaneum*
8	Lambda-cyhalothrin solid nanodispersion	*Plutella xylostella* L.
9	Chlorantraniliprole solid nanodispersion	*Plutella xylostella* L.
10	Avermectin solid nanodispersion	*Plutella xylostella* L.

the botanical pesticides (neem oil, sweet flag rhizome oil, sweet orange oil and eucalyptus oil) and microbial pesticides (entomopathogenic fungi, bacteria, nematodes and viruses) can also be formulated into nanoformulations which can be used as important component in Integrated Pest Management (IPM) programs. Hence nanotechnology has an abundant scope in insect pest management for ecofriendly and sustainable farming. Some of the nanopesticides used in the insect pest management are given in table 1.

Conclusion

The negative impacts of the chemical pesticides can be minimised by using nanopesticides as they need a lower amount of active ingredient for an effective control of the pest. Hence nanopesticides could be a promising solution for a major yield limiting biotic stress in crop plants. Nanoinsecticides have some potential human health and environmental concerns like dermal absorption and higher persistency. More studies should be conducted in the direction of assessing the risks associated with their use on the environment and human health. Education regarding the safe use of nanpesticides to the general public is need of the hour.

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