Nanopesticides: Its Scope and Utility in Pest Management

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Abstract

Pesticides have become one of the inevitable parts in Indian agriculture. The higher dosage of these chemicals on per hectare basis has led to many environmental and health hazards. The development of a new scientific area, nanotechnology has led to the development of nanopesticides. These chemicals contain the carrier molecule or the active ingredient in nano size. Several formulations viz., nanoemulsions, nanosuspensions, controlled release formulations, solid based nanopesticides have been developed by the research community. The smaller size of the chemicals helps in proper spreading on the pest surface and thus, a better action than conventional pesticides. Meanwhile, we should have a better understanding on the ill effects of these nano-pesticides after their application.

Keywords: *Active Ingredient, Carrier molecule, Controlled release, Nanoparticles*

The importance of pesticides has been increasing over the last few decades driven by the need to improve overall agricultural productivity, in order to safeguard adequate food availability and sufficiency for the growing global population. Every year in India pests and diseases eat away on an average 15- 25% of food produce. Past three financial years (FY14-16) have been a challenging year for crop protection chemicals market in India as well as throughout the world. As per Economic Survey of India, agriculture sector has grown by 4.1% in FY17. In order to offset the growing demand for food grains either the area under the production should be increased or productivity of the existing land should be improved. As the arable land is limited, increasing productivity is the only option available. This can only be achieved through usage of high yielding varieties, fertilizers and pesticides. As the crop yield increases, the incidence of pest attack rise which leads to increased demand for pesticides.

The conventional group of insecticides have several major dis-advantages like high dosage per unit crop, drift hazards, operational hazards and residues in environment, plants and in marketable produce, they also affect non-target vegetation and non-target organisms. So, they need to be replaced by an alternative pest control strategy that can overcome the above lacunas.

Nano-pesticides are one of the alternatives to overcome the lacunas of conventional group of insecticides. Nano-pesticides are plant protection chemicals, in which either the active ingredient or the carrier molecule is developed through nanotechnology. As it really indicates, the Greek origin word *'nano'* means dwarf. The major aim in the development of nano-pesticides is to lessen the environmental hazards of a pesticide active ingredient through improving the efficacy of a chemical. The absolute small size of the particles is the benefit here. The size of a nanopaticle generally ranges 1-100 nanometer and a nanometer is one billionth of a meter. When the size gets this small, particles reach a very large surface area and thus more volume of pesticides get contact with the pests. The ability of nanoparticles to permeate is due to their extremely small size and shape. Like other pesticide formulations, nano-pesticide formulations will also constitute the active ingredient, the carrier molecule and surfactants. The major benefits of these nanoparticles includes the improved solubility active ingredients, better stability of formulation, slow release of active ingredient and improvement in mobility caused by smaller particle size and higher surface area. The mode of action against target pests is expected to be enhanced with nanoparticles, as opposed to bulk materials. Moreover, nano-formulations provide systemic properties, uniform leaf coverage and improved soil properties to support their constructive use in agriculture.

FORMULATIONS OF NANO-PESTICIDES

The research in nanotechnology has led to the development of different nano-formulation which can be applied in crop protection *viz.,* nano-insecticides, nano-herbicides, nano-fungicides and nano-nematicide. Nano-pesticides are formulated according to their intended purpose as formulations improving solubility, slow release of active ingredients, prevent degradation *etc*. For achieving these purposes, modifications in the chemical nature carrier molecule have been modified and classified as organic polymer-based formulations, lipid-based formulations, nanosized metals and metal oxides, clay based nanomaterials *etc*. Some foremost nano-formulations are mentioned in this article.

Nano-emulsions: Generally an oil-in-water (O/W) emulsion is more common as a nano-emulsion where, active ingredient of the chemical is dispersed as nanosized droplets in water, with surfactant molecules confined at the pesticide-water interface. Nano-emulsions get further classified based on the quantity and type of surfactants, as thermodynamically stable and kinetically stable. If the pesticide is partially soluble in the aqueous phase and spontaneous formation of a stable emulsion happens when surfactant, pesticide, and water components are brought together, that is a thermodynamically stable nano-emulsion. The insolubility of the active ingredient make the pesticide and surfactant to initially form a two-phase system and thus, a continuous shearing make them to mix together and pesticides droplets in the nano-emulsion will remain dispersed for an extended period of time and so are considered to be kinetically stable. *Eg:* Oil in water nanoemulsion of neem oil has been developed for insect management using Tween 20 as the surfactant.

Nano-suspension: Nano-suspensions, also termed as nano-dispersions, are formulated by dispersing the pesticide as solid nanosized particles in aqueous media. In nano-dispersions, the surfactant molecules get confined at the particle surface where polar portions extending into the aqueous solution and the non-polar portions associating with the solid pesticide. *Eg:* Aqueous dispersions of nano-permethin, novaluron and β-cypermethrin have been developed by researchers.

Polymer based nano-particles: Polymer-based pesticide nanocarriers are majorly deployed in the slow and controlled release of active ingredients to the target site. Moreover, they can serve to improve dispersion in aqueous media and also as a protective reservoir. Nano-encapsulation, nano-spheres, nano-gels, nano-fibers, *etc* are some of them falling in this category.

Nano-encapsulation: Nano-capsules or nano-encapsulation are heterogeneous reservoir type structure containing an inner central cavity which confines the hydrophobic or hydrophilic active ingredient, surrounded by a polymer coating or membrane. The active ingredient in neem-azadiractin formulation can be protected through this formulation. *Eg:* Controlled-release nano-formulation of the neonicotinoid insecticide *i.e.,* acetamipirid and imidacloprid have been developed.

Nanospheres: These are homogeneous vesicular structures, in which the bioactive ingredient is uniformly dispersed throughout the polymer matrix. *Eg:* Polymer stabilized bifenthrin nanoparticles are developed as nanospheres.

Nanogels: These are also known also hydrogel nanopartciles. These are formulated by cross linking of polymeric particles having hydrophilic groups, thus absorb higher quantities of water. Chitosan nanogel is an example for this.

Nano-fibres: Nano-fibres are developed through electrospinning, thermal induced phase separation. Researchers have developed electospun nano-fibers loaded with the chemical, (Z)-9-dodecenyl acetate, an ingredient of pheromone which get embedded in the polymer matrix for the management of many lepidopteran insect pests.

SOLID NANOPARTICLES AS NANO-PESTICIDES

In addition to the above formulations, solid nanoparticles can also be used as nano-pesticides. The inert dusts, such as silica, alumina, and clays cause damage to the wax coating on the insect cuticle through both sorption and abrasion. This physical damage can cause to lose water and thus resulting in dehydration to the insect. Nano-silica particle can be suggested as an eligible candidate among solid nanoparticles due to its additional benefit to aid in increasing tolerance to abiotic and biotic stresses by the plant. However, high dosages have to be applied for a better result which can adversely affect the grain properties. Nanostructures alumina was also reported to have pesticide properties. Moreover, nano-clays developed from montmorillonite were also shown to have pesticidal function but low toxicity.

Among metals, silver, titanium oxide and copper are most preferred as nanoparticles. The bactericidal and viricidal activity of silver nanoparticles makes them favourable by nanotechnology researchers. The low toxicity, inherent charge, larger surface area and crystallographic structure increase its preference. The use of titanium

dioxide to crops has proved effective antimicrobial and antifungal activity. Nano-copper formulations can cause cell wall damage of bacterial cells and found effective against pomegranate bacterial blight at very low concentrations. Cell wall damage was observed in nano-copper treated bacterial cell.

From past one decade, considerable research has been made in the field of nanotechnology. Yet, it is only recently we are beginning to recognize how nanoparticles can impact on our lives and lead to both positive and negative results. Research in nano-pesticide development is being taken up in a faster rate but, this subject matter has not reached the public awareness or regulatory authorities so far. By and large, innovation all the time results in both benefits and problems for human and environmental health. The current level of knowledge regarding environmental fate does not allow us to a fair assessment of the advantages and disadvantages that will result from the use of nano-pesticides.

However, the major advantages of use of nano-pesticides over conventional pesticides are:

- Nanotechnology offers a tool for developing novel formulations of eco-friendly pesticides as majority of nano-pesticide formulations are highly target specific.
- Generally, targeted delivery and controlled release of nano-pesticides can improve pesticide utilization and reduce residue and pollution. For example, Nano-microcapsule formulations have slow release and protection performance because they have been prepared using light-sensitive, thermo-sensitive, humidity-sensitive enzyme-sensitive and soil pH-sensitive high polymer materials to deliver pesticides
- Nano-pesticide formulations improve adhesion of droplets on plant surface (reduces drift losses) which intern improves the dispersion and bio-activity of active ingredient *(a.i.*) of pesticide molecules. Therefore, Nano-pesticides will have high efficacy compared to the conventional pesticide formulations (*i.e.,* D-Dust, G-Granule, P-Pellet, EC-Emulsifiable Concentrate, WP-Wettable Powder, WDG-Water Dispersible Granule, *etc.*) and due to their small size, improvable pesticide droplet ductility, wettability and target adsorption when sprayed in fields has made these nano-pesticides provide efficient and environmental friendly advantages
- Nano-pesticides are extraordinary means for setting up an eco-friendly and sustainable agriculture system because it reduces the overall chemical usage, decreases the toxic residues and enhances the overall crop protection.

THE LIMITATIONS IN THE USAGE OF NANO-PESTICIDES:

- The risk that nano-particles (nano-pesticides) may pose to human and environment health is not yet fully understood.
- Nano-pesticides may also create new kinds of contamination of soils and waterways since nano-pesticides are apparently much more persistent and have higher degrees of toxicity when compared to their traditional counterparts.

Therefore a better understanding of the fate and effect of nano-pesticides after their application is required. It is a good thing that all necessary safety precautions are taken before deciding to go ahead and use new technologies on a large scale.

REFERENCE

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