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Mode of Action of Nanoparticles against Insects

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Nanoparticles (NPs) can be defined as a subclass of ultrafine particles with characteristic dimensions from 1 to 100 nm and have properties that are not shared by non-nanoscale particles with the same chemical composition. The basis of the 100-nm limit is the fact that unique properties that differentiate particles from the bulk material typically develop at a critical size of under 100 nm. NPs are complex molecules with three distinct layers: (a) the topmost being surface layer (functionalized with an array of small molecules, metal ions, surfactants, and polymers), (b) the shell layer, and (c) the core layer. The shell and core layer differ chemically in every characteristic. The core, the central portion, is by itself the nanoparticle. The loading of active pesticide compounds on NPs, namely, surface adsorption, nanoparticulate polymer shell encapsulation, covalent binding by various ligands, and nanopolymer matrix entrapment.

Nanotechnology is the art and science of manipulating matter at nanoscale. The design, characterization, production and application of structure, device and system by controlling shape and size at nanoscale.

- **'Nano'**- Greek word means **'Dwarf'**
- 1 nm = one billionth (10^{-9}) of metre
- Size range between **0.1 and 100 nm**

NPs can easily penetrate into plant cells making them a ''nanocarrier'' transport system. They are able to deliver products accurately, as they are customized to transfer a particular biomolecule to the cell, tissue, or organism when needed. Physical characteristics such as, shape, size, crystal phase, chemical configuration, and surface-to-volume ratio are the vital parameters that define the outstanding characteristics of these nanomaterials (Athanassiou *et al*., 2018).

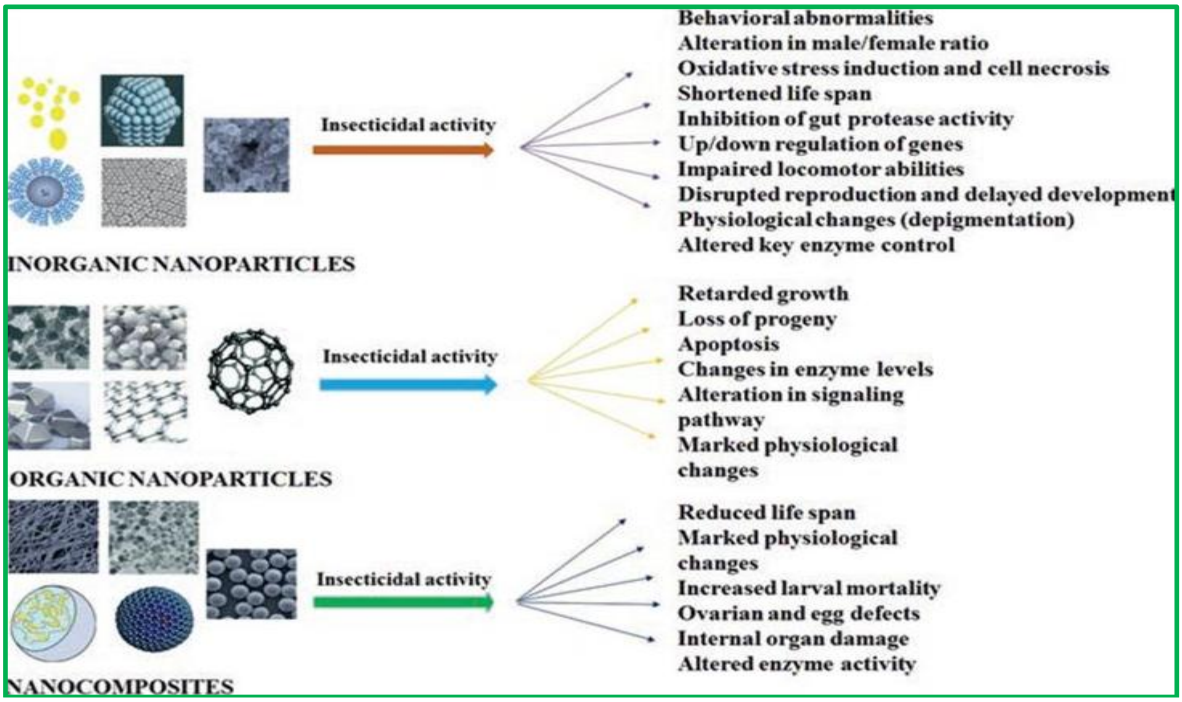
The employment of nanoparticles obtained through various synthesis routes as novel pesticides recently attracted high research attention. However, precise information on the mechanisms of action of nanoparticles against insects and mites are limited, with the noteworthy exception of silica, alumina, silver, and graphene oxide nanoparticles on insects.

Silver nanoparticles also reduced acetylcholinesterase activity (Fouad *et al.*, 2018). Besides, silver nanoparticles up and downregulate key insect genes, reducing protein synthesis and gonadotrophin release, leading to developmental damages and reproductive failure (Nair *et al.*, 2011).

Gold nanoparticles can act as trypsin inhibitors and disrupt development and reproduction (Patil *et al*., 2016). The toxicity of silica nanoparticles is due to their binding to the insect cuticle, followed by physio-sorption of waxes and lipids, leading to insect dehydration (Shoaib *et al*., 2018).

Zinc oxide nanoparticles shows several morphological and histological abnormalities in insects, including shrinkage in the abdominal region, thorax shape changes, midgut damages, loss of lateral hairs, anal gills and brushes (Banumathi *et al.*, 2017). Graphene oxide nanoparticles have a significant impact on insect antioxidant and detoxifying enzymes, leading to oxidative stress and cell death (Dziewięcka *et al.*, 2016).

Nanocomposites nanopolymer-based insecticides with essential garlic oil loaded on polyethylene glycol-coated polymer-based nanoparticles was used to control red flour beetle adults (Yang *et al.*, 2009). Nanoparticles improve the bioavailability properties and minimize the nontarget toxicity against wildlife, food, and environmental residues.



Different nanobased insecticides along with their insecticidal effects

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