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Nanopesticides- A Promising Tool For Sustainable Pest Management

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Nanotechnology is a new phenomenon that is becoming increasingly relevant in today's technological landscape. It has emerged as having the potential to change agricultural methods over the last decade. Nanotechnology's use in pesticide delivery is quite new and yet in its early phases of research. Nanopesticide is a crop protection chemical in which the carrier molecule is developed using nanotechnology. Nanopesticides have different properties like slow release of active ingredient; improved fluidity and they can penetrate the interior places due to their larger surface area and small size. In addition to enhance the mode of action of the pesticide, it also improves the stability of formulation and increases the solubility of the active ingredient. Moreover the biologic properties of the pesticides have been improved when applied as nanoemulsion formulations by increasing bioavailability and cell absorption. Increased active ingredient absorption has resulted in effective diffusion in to the plant cuticle and wettability

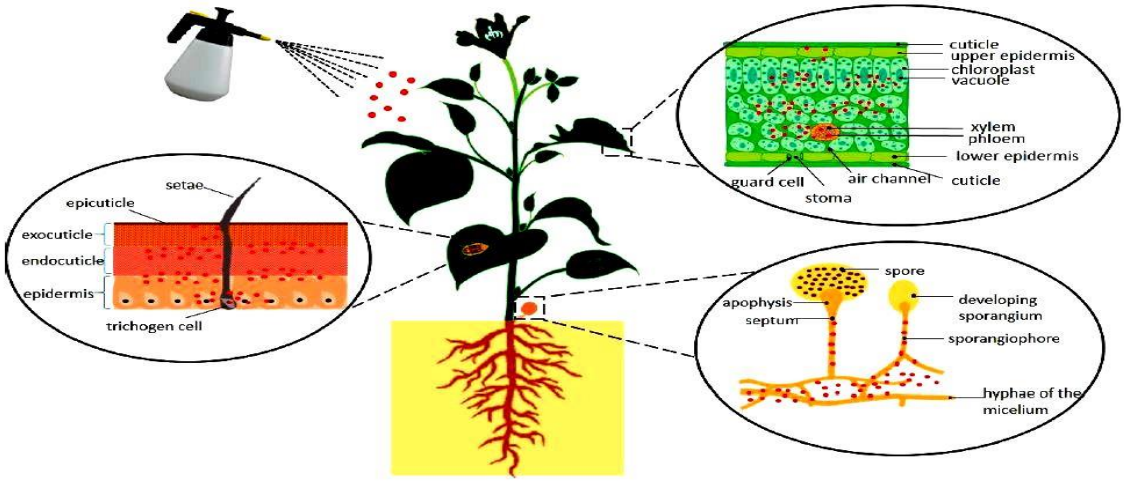

Fig 1: Depiction of penetration of nanoemulsion formulation of pesticides via insect cuticles, leaves surface, and fungal bodies. (Adopted from Mustafa et al. 2020).

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The increased lipiphilic property of the nanoemulsions was further used for effective impregnation of pesticides in to insect cuticle. This phenomenon helps in easier disintegration of the insect's waxy cuticular layer, causing rapid dehydration and, ultimately the death of insect. For various intended purposes, different nano formulations have been manufactured by modifying the chemical nature of the carrier molecules. Some of the promising nano-formulations are nano-emulsions, nano-fibers, nano-suspensions, nano-spheres, nano-gels, micelles, liposomes, inorganic nanocages etc, for which the base material of the carrier particles were mostly, nano metals, polymer based/ clay based or lipid based nano encapsulations.

Nanoemulsions:

Nanoemulsions are the oil in water emulsions, with a droplet size 20-200 nm and are also known as mini emulsions or ultrafine emulsions. Here the two immiscible liquids i.e., active ingredient (oil) is dispersed as nano sized droplets in water, which are stabilized by surfactant molecules to form a single phase. Based on the type and quantity of the surfactant they are considered as thermodynamically and kinetically stable isotropic dispersions. Oil in water emulsion of β-cypermethrin performed better compared to commercial microemulsions in terms of stability. When, nanomeulsion with nonionic surfactant Tween 20 and water and the active ingredient neem oil is used, the droplet size has decreased improving its larvicidal efficacy.

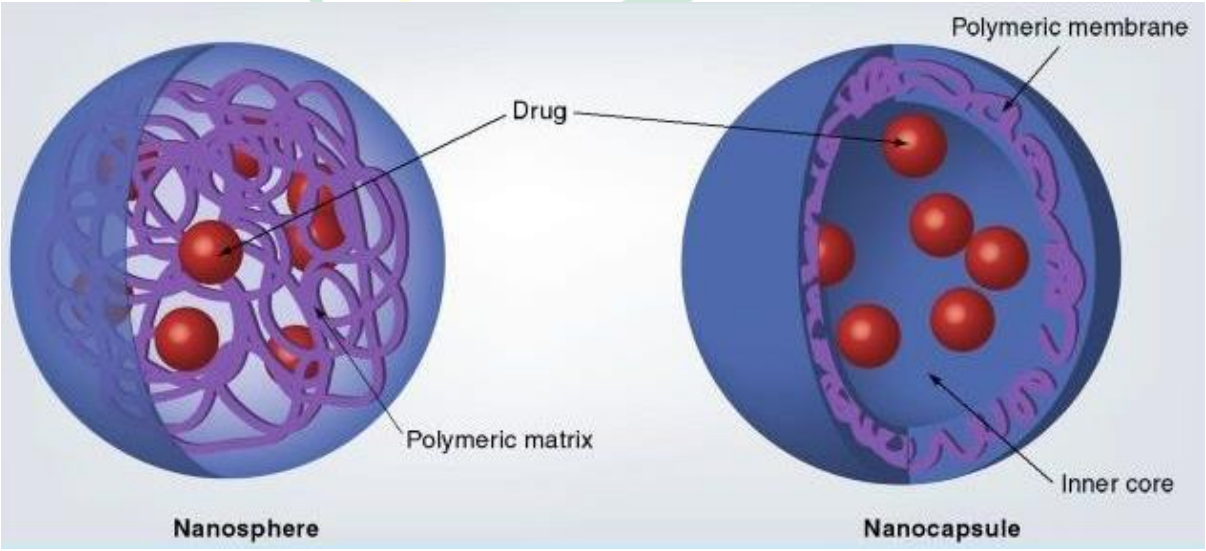

Fig 2: Differences in the core shell arrangement of nanosphere and nanocapsule.

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Nanocapsules:

Nanocapsules are heterogeneous vesicular systems which contains an internal central cavity defining a hydrophobic or hydrophilic agent, surrounded by a polymer film or coating. The internal central cavity/Core consists of active ingredient or pesticide or sometimes the active ingredients are adsorbed on to the polymeric shell. Polyentylene glycol is used an encapsulation material with active ingredient garlic essential oil to reduce its volatilization rate; nanoencapsulated lansiumamide enhanced its nematicidal activity.

Nanospeheres:

Nanospheres are the homogeneous vesicular systems where active component is uniformly disseminated throughout the polymer matrix. Avtive ingredient Bifenthrin nanoparticles were stabilised by polymers when created as nanospheres.

Nanofibers:

Nanofibers are produced using electrostatic spinning and thermal phase separation. An electrospun nanofiber containing the chemical substance (Z)-9-dodecenyl acetate, a pheromone component embedded in a polymer matrix that can be used to combat many lepidopteran pests.

Nanosuspensions:

Nanosuspensions are liquid dispersion of solid nanoparticles. Nanosuspension is also referred to as "Nanodispersion." Nanosuspension is a colloidal dispersion of the active ingredient where surfactants and polymers, or a combination of both are used to stabilise the product. Eudragit S 100 (polymer), a nanosuspension improved the penetration capacity into the plants; this is because the particle size is smaller than the classical suspension.

Nanoggels:

Nanogels also called hydrogel nanopartcles, formulated by aggregating polymeric particles having hydrophilic groups. This hydrophilic nature enables an electrostatic interaction creating a hydrogen bond among them, thus absorb higher quantities of water. Chitosan nanogel consists of *Lippia sidoides* oil has increased effective larvicidalin comparision to pure form, due to slow and sustained release of Lippia sidoides oil.

Nanomicelles:

Nanomicelles are self-assembling colloidal dispersions with a hydrophobic core and hydrophilic shell with nanosized particles ranging from 10 to 100 nm. Their unique properties

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like size, solubility or exposure to the environment makes them use indispensable in pest management. Nanomicelles, amphiphilic chitosan derivative with active ingredient rotenone has a increased solubility (up to 26.0 mg mL^{-1}) ie. 13000 times higher than that is available in free water (about 0.002 mg mL^{-1}).

Liposomes:

Nanoliposomes also known as submicron bilayered lipid vesicle composed of a phospholipid bilayer (or two or more bilayers separated by a water interface) that has a central fluid core. During the formation of vesicles, hydrophilic materials are trapped or encapsulated in the water layer. The region (including the central core) that is a hydrophobic molecule is incorporated into the lipid domain of the bilayer membrane or vesicle. Chitosan coated lipid entofenprox liposomes better pest control efficacy was observed for a longer period.

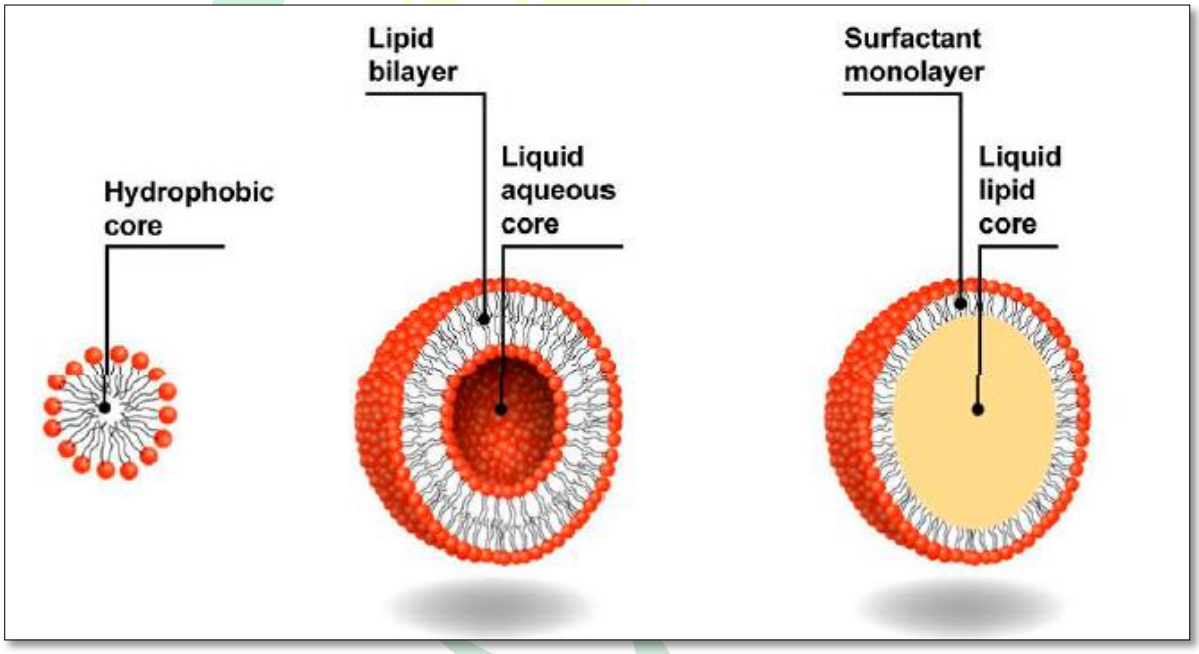

Fig 3: Differences in the core shell arrangement of Micelle, Liposome and Nanoemulsion droplet.

Conclusion:

When compared to conventional pesticides, nanoemulsion-based insecticides have numerous advantages. The target specific properties nano formulations are outstanding, indicating that they have a beneficial impact on environment and natural enemies. When nano formulations are used correctly, they can trigger the controlled release of active substances to

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the desired location and reduce the residues and pollution. Nanopesticides help in increasing the adhesion property of formulatiohs and help in reducing the drift losses and improve the dispersion of active ingredient. However, most of the earlier works has been focused on invitro studies only and work on in-vivo studies and phytotoxicity is meger. Further studies are necessary to establish nano formulations for pest managemet in to real applications.

Fig 3: Differences in the core shell arrangement of Micelle, Liposome and Nanoemulsion droplet.