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Nano-insecticides: A way forward in Insect Pest Management

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INTRODUCTION

Agriculture is one of the most important sources of livelihood, employing over 19% of the global population. The present-day agriculture is constrained by several bottlenecks in maintaining productivity with shrinking resources. Crop productivity is hampered by a variety of abiotic and biotic stressors. Pests including weeds, insects, diseases, nematodes etc. causes around 20-40% crop damage (FAO, 2021). Insect pests are reported to inflict 18-20% loss of agricultural production globally and crop losses from insect pests are increasing (Arora and Sandhu, 2017). Human utilizes several management strategies *viz.*, cultural, physical, mechanical, biological, biorational and chemical methods to contain the harmful agricultural pests from causing economic damage. However, over-reliance on different chemical-based pesticides used in crop protection are directly or indirectly affecting living beings and the environment. The drawbacks and concomitant problems associated with the existing arrays of pest management options require some alternative technology and nanotechnology has evolved as one of the most effective methods in the management of insect pests in agriculture.

Nanotechnology as an emerging field of science

Nanotechnology is often regarded as the fifth revolutionary technology of the previous century (Chhipa, 2017). Chowdappa and Gowda (2013) define nanotechnology as the control of objects with dimensions ranging from 1 to 100 nanometers (nm).). The physical, chemical, and biological properties of nanoscale materials significantly differ from those of bulk materials and individual molecules (Li *et al.*, 2001). It has long been utilized in multiple disciplines and is a recent technological innovation in agriculture. In the last two decades, the knowledge accumulated in this field has been translated and increasingly being used in the agricultural sector for the development of plant-protecting agrochemicals (Mattos *et al.*, 2017).

Scopes and approaches of using nanotechnology in insect pest management

Nanomaterials are promising molecules for insect pest management. They can be used through the formulations of nano-insecticides and nano-encapsulation for slow release of active ingredients for enhanced productivity etc. (Bhan *et al.*, 2018). Nanotechnology can also be used to deliver DNA and other desired chemicals into plant tissues for protection of host plants against insect pests. Nanoparticle mediated gene (DNA) transfer can serve as precise tool in development of transgenic plants. Nanomaterials are also used for manufacturing different kind of biosensors useful in pest detection and remote sensing devices required for precision farming. Calcium carbonate nanoparticles are also reported to enhance tolerance of plants to insect pests (Hua *et al.*, 2015).

Nano-insecticides

Nano-insecticides are emerging tools for pest management where either the active ingredient or the carrier molecule is at nanoscale. They differ from conventional formulations mainly in terms of magnitude and surface characteristics. The extremely microscopic size of nanoparticles is a gift. Because of their smaller size, nanoparticles have a bigger surface area and so more insecticides get into touch with the insect pests (Rajna *et al.*, 2019). Thus, very small amount of formulation can efficiently manage the pests and thereby minimise pesticide load (Kumar *et al.*, 2015). The major objectives of nano-formulations are enhanced solubility of poorly soluble a.i., slow release of the a.i. and prevention of premature degradation of the a.i. (Shah *et al.*, 2016). Furthermore, nano-formulation allows for the selective, targeted, and long-term controlled release of pesticides, which is more environmentally sustainable. A wide range of natural or synthetic particles such as carbon, silicates, metal, metal oxides, non-metal oxides, ceramics, clays, layered double hydroxides, polymers, lipids, dendrimers, proteins, quantum dots etc. used for production of pesticide nano formulations (Niemeyer *et al.*, 2001). A variety of nano formulations are available in the form of nanoparticles, nanocapsules, nanogels, nano-emulsions etc.

Success stories

In case of many compounds, nanoparticles can themselves act as insecticides. For example, surface charge modified hydrophobic nano-silica (~3–5 nm) successfully suppress a range of insect pests of agricultural and veterinary importance (**Ulrichs *et al.*, 2005**). Nano-Al_2O_3 dust act as physical poison against *Sitophilus oryzae* (Stadler *et al.*, 2010). Stadler ***et al.* (2010)** reported nanostructured alumina as a cheap and reliable alternative for management of *S. oryzae* and *Rhyzopertha dominica* in wheat.

Garlic essential oil (EO) in Poly Ethylene Glycol coated nanoparticles provide long term control against *Tribolium castaneum* (Yang *et al.*, 2009). Nanoencapsulated EO of *Carum copticum* can effectively suppress diamond back moth (Jamal *et al.*, 2013). Myristic acid-chitosan nanogels of *Carum copticum* EO are effective against wheat weevil, *Sitophilus granarius* (Ziaee *et al.*, 2014). Kang *et al.* (2012) reported enhanced efficacy of Pyrifluquinazon in Chitosan-coated nano formulation for management of *Myzus persicae*. Nanocapsules of pyridalyl and methomyl provide better control of *Helicoverpa armigera* and *Spodopter frugiperda*, respectively (Saini *et al.*, 2014; Sun *et al.*, 2014). Slow-release pheromone, *i.e.*, methyl eugenol nanogel provides long term control against *Bactrocera dorsalis* in various fruit orchards (Bhagat *et al.*, 2013). Nanoparticles have also been successfully utilized for delivery of bio-insecticides. An entomo pathogenic fungus, *Nomuraea rileyi* coated with chitosan nanocarrier efficiently suppressed *Spodoptera litura* with reduced dosage (Chandra *et al.*, 2013).

Conclusion and future prospects

Insect pests are one of the most dreading biotic obstacles in agriculture and researchers are constantly searching for novel strategies to combat them. Over-reliance on chemical insecticides causes a series of problems, such as environmental pollution, pest resistance, harmful effects on non-target biota and human health hazards to mention a few. As an alternative, the application of nanotechnology in insect pest management has emerged as one of the most promising ways to overcome the problems associated with conventional pest management methods. Although the use of nanotechnology for controlling insect has already been started but the pace of development and widescale adoption is not up to mark. Dedicated multi-disciplinary research for exploiting the entomotoxic effects of a greater number of nano particles and developing protocols for upscaling the synthesis of nano formulation of agrochemicals is needed. Furthermore, the biosynthesis of nanoparticles from microbes and plants is a promising way for ecofriendly pest management. There is a long way to go in nanopesticide research, and different ways are probed into for reducing off-target effects and other demerits of nanopesticides. Large scale on-farm and off-farms trials is required to evaluate the ecological effects of nano formulations and standardize the doses and application method for easy adoption. In toto, it can be concluded that nanotechnology can serve as a brilliant tool for pest management and has lots of potentials for its sustainable utilization in green agriculture.

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