Annals of R.S.C.B., ISSN:1583-6258, Vol. 26, Issue 1, 2022, Pages. 1605 - 1615
Received 08 November 2021; Accepted 15 December 2021.

Nanotechnology: A New Technology in Insect and Disease Control

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Abstract

Nanotechnology has a broad range of applications in the sectors of agriculture, industrial and medicinal sectors. Conventional toxic chemicals harm the fate of the environment which has encouraged researchers to develop different formulations of nanoparticles. These formulations have changed the characteristic properties of nanoparticles. Nano encapsulation and nano emulsions or polymer-based have improved water solubility; the dissolution rate of complex compounds while keeping the consistency of active compounds which function as insecticides remains the same. In this review importance of developing eco-friendly nanoparticle-based insecticides and management of plant disease by nanotechnology for sustainable agriculture are being acknowledged.

Keywords: Insecticides, Nano formulations, improved characteristic property, the active compound, environmental fate, plant disease management

Introduction

The insect is one of the biggest populations in the entire universe. Crops damaged by insects, pests, and pathogenic organisms have a direct impact on the national economy(Oerke 2006). Around 50% global population resides in Asia which included majorly only developing countries and has to face food shortages due to natural calamities like floods, storms, and drought. For thousands of years, per capita loss has been reported even after the excess or moderate use of insect-killing chemical agents(Mukhopadhyay 2014, Mittal, Kaur et al. 2020). Nanotechnology is the most advanced, promising, and novel field that has revolutionized major sectors of industries and agriculture(Shrivastava and Dash 2009, Marchiol 2018). It has enormous potential uses and benefits synthesized nanoparticles served as insecticides to prevent plants from pathogens and insects. These organisms are present in

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all kinds of the environment(Kumar, Nehra et al. 2019). The management of insect pests through the formations of the several assemblies of the nanoparticle is one of the considerable methods to reduce environmental stress which is due to the use of toxic chemicals to kill insects and which kill insects but in return, it is a major cause of environmental pollution e.g. soil pollution and water pollution(Sheikhavandi 2015). The advancement in nanotechnology in the last decades has enabled the development of active compound assembly of nanoparticles which bound complex compounds in core or surficial region of nanoparticle to kill insects in order to control plant diseases. Thus nanotechnology has played an important role in economic development of a country. In this review, the main focus is to highlight major contributions of nanotechnology in producing high yield of crops by providing them protection from insects(Ramezani, Ramezani et al. 2019).

Nanotechnology

Nano is a Greek word that means dwarf. This technology is named nano as it includes the particles of nanometer-sized particles in the range of 1-100 nm(Hulla, Sahu et al. 2015). Nanoporous zeolites are one of the active assembly that allows the slow release of major components of compounds that targets the killing of insect species(Ramesh, Biswas et al. 2010). Nano capsulation is another common kind of assembly of nanoparticles that are directed to attack the different membranous parts of insects which if interact with plants applied with nanoparticles based insecticides(Boehm, Martinon et al. 2003, Lee, Min et al. 2009). Nanosensors are also used in the soil to detect the population of insects in certain irrigation land. These special assemblies of nanoparticles differ in the atomic arrangement which serves to the change in physical, chemical, and biological properties of synthesized nanoparticles thus the mode of action is changed but carry the very same function of killing insects(Khot, Sankaran et al. 2012, Ali, Ahmed et al. 2022).

Presence of natural nanoparticles in insects

Latest studies have revealed that several kinds of nanoparticles are naturally produced in the wings and the thoracic regions of insects. The size of these nanoparticles ranges from 200 to 1000 nm. These structures are round and largely present on the apex, and lateral sides but some are also protruded in the wing regions. One of the examples is cicada which has an assembly of a hexagonally packed array of nano-sized orderly structures. These particles assist insects in aerodynamic of an insect during flight. In some reports, the presence of such nanoparticle structures also exists in the eye compounds of some special insects. These natural assemblies have provoked scientists to find further effective ways of developing eco-friendly insect-killing nanoparticles. Naturally produced nanoparticles in insects and apply of synthesized nanoparticles to plants for their killing is one of the best combinations in the disease management strategy of plants. Recent reports also suggest the development of nano-sized photodegradable insecticides are being prepared that are very active in almost all pathogenic insect species within a very short time frame(Guan, Pearce et al. 2008).

Nano insecticides

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Nano insecticides are composed of several products like inorganic ingredients in form of metal oxides or metal zeolites, organic compounds in form of polymers, and various oil-based micelles assemblies. These nanoformulations allow the release of the active ingredient in an organized manner i.e. slow and target-specific. Therefore, these nanotechnologies serve plants by providing them with long-term protection against premature degradation of sensitive regions of plants and crops due to rapid attack of insects(Murugan, Raman et al. 2016, Awad, Ibrahim et al. 2022)**.**

Importance of formation of assemblies of nanoparticles serving as insecticides

Several nanoformulations are engineered to have a significant impact on the fact of active compounds function as an insecticide. Summary of applications reported in different research studies are as follows:

1. New complex compounds which are poorly understood can be packed inside nanoparticles of silver to check whether it is safe for the environment or not.
2. Current knowledge regarding nano pesticides is not enough. Combined analytical techniques are still required to explore to detect novel characteristics of nanoparticles i.e. size shape, nature, and surficial properties. This will allow targeted and slow release of active compounds which has long-term fruitful prospects(De, Bose et al. 2014).

Innovative approaches are used to synthesize assemblies of Nanoparticles serving as insecticides

Nanotechnology is a multi-arrayed field with thousands of applications. These nanoparticles serve as fertilizers, plant hormonal boosters, and eco-friendly agrochemicals. The best possible nano moieties are being discussed(Shah, Wani et al. 2016, Shahid, Naeem-Ullah et al. 2021).

Nanosphere

In the nanosphere, polymeric assembly of nanoparticles forms aggregates. The active compound is evenly distributed throughout the polymeric matrix.

Nanocapsule

Insects are killed by forming a chemical-based capsule structure and the active compound is evenly distributed in the core region of the spherical region of the nanocapsule(Shah, Wani et al. 2016).

Nanogels

Nanogels are composed of hydrophilic cross linkers which are highly toxic due to high water and active compound absorbance capacity thus killing most of the insects in very less time. The active compounds formed in gel form have very efficient and specific against plant-eating insects(Mukhopadhyay 2014).

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Micelles

Insecticide ingredients are mixed to form aggregates in an aqueous solution of hydrophilic or hydrophobic nanoparticle-based moieties(Shah, Wani et al. 2016).

Inorganic moieties of nanoparticles function as insecticides

The advancement in nanotechnology has allowed the formation of efficient nanoparticles such as ZnO, Cu, SiO_2, and Ag. These nanoparticles depict a broad spectrum in their application. These nanoparticles have many other advantages other than protecting plants. Many reports have confirmed that nanoparticles amended plants use relatively very less amount of water and exert relatively very less stress on the environment (Hajji-Hedfi and Chhipa 2021).

Zinc is an essential nutrient for plants. Zinc has an important role in part development and growth. Zinc is also present in many natural hormones that have a role in protecting from insects or pests. Many reports have claimed the supreme power of nanoparticles in form of oxides e.g. ZiO_2 has strong anti-fungal activity and prevents insect attack to fungi associations (Servin, Elmer et al. 2015). Silver Nanoparticles have a great contribution in the field of living organisms and pest control and management. Silver has the natural power to kill pathogens using that character green nanotechnology has been introduced. Silver nanoparticles have antibacterial, anti-viral activity.(Rathor, Chopra et al. 2014, Huang, Chen et al. 2018, Bhattacharya, Epidi et al. 2020). Nano dust particle of aluminum is one of the great discoveries. These nanoparticles has significant role in the protection of plants against deadly disease causing insects. Stadler et al. and Buteler et al.reported that multi solutions of compounds of alumina along its salt derivate act as key precursors to mend routes for the preparation of aggregates of novel nano particle with extreme power to neutralize the toxicity of insects infused in plants. (Stadler, Chi et al. 2010, Paula, Rodrigues et al. 2012, Butler, Peeler et al. 2015). These reports also suggest that *S. oryzae*is efficiently protected by the use of engineered dust nano particles of aluminum(Athanassiou, Kavallieratos et al. 2018). Silicon is an element that is well known for providing plant tolerance against various biotic and abiotic stress e.g. water stress, metal ions toxicity (Shah, Wani et al. 2016, Bayat, Pakina et al. 2019). Different formulations of silicon especially nanoparticles of potassium silicate is potential candidate to control plant from fungal and insect attack.

Nanoemulsions

Nano emulsion has been the favorite formulation because it has numerous advantages over conventional emulsions(Flanagan and Singh 2006, Solè, Solans et al. 2012).Ostwald ripening and phase inversion methods are the considerably the best method for the micro emulsion formation. Nano emulsions have metastablecharacteristic which mean nano particles of in this form have very high kinetic stability(Morales, Gutiérrez et al. 2003).It is also reported that non-ionic solutions can destroy the consistency of these nano particles very easily(Liu, Fan et al. 2010, Wu, Wang et al. 2010). It is always recommended to dilute the micro emulsions in 20% surfactants to standardize the droplet size up to 20-200 nm (Anton and Vandamme 2009, Shang, Li et al. 2009, Anjali, Khan et al. 2010).

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Active compounds in novel nanoparticles acting as insecticides	References
Active compounds in metal and organic nanoparticles acting as insecticides	
Chlorfenapyr	(Vurro, Miguel-Rojas et al. 2019, Shahid, Naeem-Ullah et al. 2021)
Imidachlorprid	(Kumar, Nehra et al. 2019)
Active compounds in double hydroxides and clay nanoparticles acting as insecticides	
Diuron	(Yusoff, Kamari et al. 2016)
Cinnamic acid	(Mishra, Dash et al. 2018)
Active compounds in porous hollow silica nanoparticles acting as insecticides	
Avermectin	(Feng, Chen et al. 2020)
2,4-dichlorophen-Oxyacetate	(Shah, Wani et al. 2016)
Alpha-naphthalene acetate	(Mondal 2016, Pakeerappa, Singh et al. 2021)
Active compounds in polymer-based nanoparticles acting as insecticides	
Terbuconazole	(Bernal-Chávez, Gutiérrez-Ruíz et al. 2022)
Imidacloprid	(Shah, Wani et al. 2016, Sudhaik, Raizada et al. 2020)
ThiamethoxamC	(Bernal-Chávez, Gutiérrez-Ruíz et al. 2022)
Arbofuran	(Ojha, Singh et al. 2018)
Thiram	(Prado-Audelo, Luisa et al. 2022)
Ethiprole	(Shah, Wani et al. 2016)
Active compounds in nano emulsion-based nanoparticles acting as insecticides	
Riazophos technical grade	(Shah, Wani et al. 2016)
Emamectin-benzoate	(Kumar, Kanwar et al. 2021)
Active source of essential oil used in nano nanoparticles acting as insecticides	
Peppermint	(Shah, Wani et al. 2016)
Rosemary	(Ataei, Azari et al. 2020)

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Thyme	(de Oliveira, Campos et al. 2014)

Table 1: Active compounds used in several nano sized formulations, directed to function as insecticides

Management and disease controlby using nanotechnology as modern approaches

Broad range applications of nanotechnology in the field of agriculture have provided efficient methods to manage and control plant diseases. This has increased the yield up to 30 folds relative to the use of conventional irrigational strategy. Several studies confirmed nano particles when prepared by novel scientific techniques has developed eco-friendly pesticides, insect repellents and insecticides(Worrall, Hamid et al. 2018).

The usage of Nano particles has been reported since the development of homeopathic medicines where nano sized plant extracts were mixed to cure certain diseases(Shahid, Naeem-Ullah et al. 2021). Many old formulations of nanoparticles were having very short life span and were ready soluble in water, thus the functioning capacity was also relatively for a shorter period. Engineered nanoparticles have assisted in producing more stable nanoparticle which has functioning capacity for longer time. Apply of such nano particle is very beneficial in the agricultural domains. It is being reported that US government has donated 4% expenditure budget to promote the use of nano particles in to revolutionize the environmental and health sector(Giunti, Campolo et al. 2021).

With numerous efforts many products are being reported which are purely made from nano particles and have lots of benefits over the use conventional toxic chemicals to protect plants and crops from insects. Porous hollow silica based nano particles (PHSNs) when loaded with validamycin as an active compound is proved to be very potent insecticide(Qian, Shi et al. 2013). It provided the best delivery system of water soluble pesticides with characteristic property of slow and controlled released. This provides long time protection to plants from insects (Nuruzzaman, Rahman et al. 2016). Another report by Teodoro et al. 2010 present the study about insecticidal activity of nano particles prepared from alumina. These nano particles were prepared against insect pests i.e.Rhyzoperthadominica which is a major insect pest. This pest has high growth in stored food supplied around the world. Report also suggestedthat continuous exposure to such alumina containing nano particles for three days not only killed insect pests but also resist their growth. Those inorganic nano particles were launched commercially to be used as insecticides. It provided cheap and reliable alternative to save food and plants from insects(Giunti, Campolo et al. 2021). The management of the environment and health system by this method has miraculously encouraged scientists to conduct further research studies in this wide domain of nano particles.

Conclusion and potential prospects

In the past hundred years, the frequent use of conventional pesticides has considerably destroyed the environment. Nanoparticles-mediated insecticides have played an important role in the field of agriculture. The major objective of the formation and application nano insecticides is to enhance the stability and solubility of less soluble compounds which possess

difficult or slow release of targeted active compounds. Tremendous efforts are being reported and numerous scientific researches are ongoing to resolve food shortage issues. Various nano-based formulations have been systematically addressed in this review to protect and manage

The next era is purely a bright time for the prevalence of nanotechnology because of best and novel characteristic properties of nano scale ingredient. Theseingredients are highly specific and toxic to kill specific pest specie i.e. premature plant damaging insects. Many toxic pest control chemicals have destroyed not only the sensitive tissues of plants but also harm the health of humans and animals equally. Nanotechnology is a smart approach to save human health, the animal life, plant life and the global economy. Nanoscale devices with novel characteristics are a remedial action to restore the environment for future generations because 60% economy of developing countries is based on agriculture. More scientific research to explore efficient nanoparticle-based insecticides will be a great step toward environmental fate and can potentially enhance the yield and nutritional values of food. The main prospect is nanotechnology-based gene transfer in the plant. It will be super eco-friendly and will prove the best alternative to a toxic chemical that is vigorously harming nature(Athanassiou, Kavallieratos et al. 2018).

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