



Nanopesticide: Current Status and Future Possibilities



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Abstract

Excess use of chemical pesticides in agriculture assisting the accomplishment of agri-food production targets. But, indiscriminate use of chemical pesticide is the serious concern for environment and human, which deteriorating the soil health, nutritional quality of food and increasing resistance in phyto-pathogens and pests. Nanotechnology provided the sustainable solution in this regard by development of nanopesticide. In the current review, we explored the development of nano-pesticides and their impact on agricultural practices. We also summarized type of nano-pesticides, advantages and drawbacks of nanopesticide application and their future possibilities.

Keywords: Nanopesticide; Nano-formulation; Nano-emulsion; Metal oxide; Nano-gel

Introduction

The growing population of world demanding the surge in production of agriculture output i.e. agri-food production but, increasing plant pathogen and pest problem hampering the target achievement and generating pressure on government and non-government agencies to adopt new technology for fulfilment of food production goals. It is estimated that worldwide plant disease caused 13%, insect 14% and weed 13% loss in food production and accounted 2000 billion dollars economic loss per year [1]. To prevent loss of crop, green revolution provided the chemical pesticide to agriculture during 1930-1960 but indiscriminate use of synthetic pesticides like DDT, pyrethroids, methyl bromide, organophosphates and so forth generated environmental, health issue, resistance development in pest and detrimental impact on non-targeted organisms [2-5]. More than 20000 deaths has been estimated every year by World Health Organization due to negative effect of the pesticides [6,7]. Bio pesticides are the possible solution for reduction of adverse impact of chemical pesticides and environmental balance but their efficacy at different geographical conditions and slow pest control activity making them least choice of farmers.

In current decade, nanotechnology showed large scope in different fields like medicine, electronics, catalysis, remediation and agriculture. Nanoparticles have specific morphology, size, high surface area and high reactivity, which provide them high chemical, physical and optical properties. In Agriculture, nanotechnology provided new tools in the form of nanofertilizer,

nanopesticide and nanosensorto conventional agricultural practices [8-10]. Nanopesticide are small engineered structure which provides pesticidal properties or formulation of active ingredient of pesticide in nanoform. These nano structures have shown slow degradation and controlled release of active ingredient for long time. The above said properties of nanopesticide make them environmentally safe and less toxic in comparison to chemical pesticide.

In this contest, researchers have developed different type of nanopesticide like nanocapsulated formulations, nanoemulsion, nanogel, nanospheres, and metal and metal oxide nanoparticles. Detailed review on the development on the nanopesticide have been given by Kah & Hoffman [11]. Brief description of such inventions are given below [10].

Nanopesticide: Current Status

Nanocapsules have shown controlled release and slow degradation properties of active ingredient (AI), making them more efficient in controlling plant disease and pest. Different type of polysaccharide materials have been incorporated in synthesis i.e chitosan, poly ethylene glycol (PEG), starch, cellulose and polyester substance [12-16]. Further, Bhan et al. [17] developed temephos and imidacloprid containing PEG encapsulated nanopesticide with melt-dispersion method and find more active against larvae of *Culex quinquefasciatus*. Further, synthesized solid lipid and polymeric nano-capsules loaded with carbendazim and tebuconazole for fungicide

applications [18]. To minimize the harmful effect of herbicides, Poly (epsilon-caprolactone) (PCL) nanocapsule has been developed for controlled release of atrazine and found enhanced herbicidal activity in comparison to commercial formulation of atrazine [19]. Similarly, Werdin et al. [20] developed PEG nanoparticles with essential oil (EO) extracted from Geranium sp. and Citrus reticulata for insect *Blatella germanica* control. They found that EO containing PEG nanoparticles showed slow release of terpenes that enhanced the toxicity multifold to insect *Blatella germanica*. The PEG nanoparticles loaded with garlic essential oil were applied to prevent pest in post harvested and stored products [21].

Nanoemulsions (NEs) were also developed to improve solubility and spreading capacity of pesticide by dispersion into two liquid phases. The advantages of NEs were found in greater spreadability, wettability, and superior mechanical stability in comparison to normal emulsion. These characteristic of NEs found helpful in less degradation and volatilization of active ingredient (AI) and improve their bioavailability for long time period [3,22,23]. Wang et al. [24] developed surfactant based nano-emulsions of pesticide beta-cypermethrin. In India, nanoemulsion of permethrin and nanoemulsion of neem oil were developed by Anjali et al. [25,26] and reported that size of droplets affected the activity of nanoemulsion. Still, nanoemulsion of different fatty acid methyl esters, organosilicones, alkyl glucosides and Tebuconazole (TBZ) were formulated to improve their efficacy against different pest [27-29]. Further, pheromone based nanogels were also synthesised using methyl eugenol to control fruit pest [30]. Brunel et al. [31] used chitosan nanogel with copper to enhance antifungal activity against *Fusarium graminearum* and found synergistic effect of chitosan and copper to inhibit the fungal pathogen.

Different type of metal or their oxide were also explored in development of inorganic nanoparticle for antimicrobial and insecticidal applications [32-35]. Nanoparticles association with insecticide increased their activity many folds by providing more loading capacity and controlled release patterns. Chlorfenapyr associated with silica nanoparticles showed twice insecticidal activity in laboratory and field tests [36]. In other study, silica nanoparticles coated with 3 mercaptopropyltriethoxysilane were found more efficient against insect. Similarly, calcium carbonate and porous silica particles showed controlled release of validamycin, make them more active for longer period [37,38]. Nanoform of copper (Cu) showed four order higher activity against bacterial blight on pomegranate at 10000 times less concentration of recommended Cu [39]. Titanium dioxide nanoparticles were also explored for bacterial spot disease of tomato and rose in pristine form or doped with zinc and silver [40,41]. Alumina nanoparticles were exhibited greater mortality against different pests like *Sitophilus oryzae* and *Rhizopertha dominica* [42,43]. Biosynthesised nanoparticles have also been introduced in nano-pesticide industry to provide eco-friendly

nanoparticles and found more effective and stable tools to control phytopathogens and pest [44,45].

Nano-formulation were also developed to improve efficiency, stability and reduction of effective pesticide concentration, like nanoformulation of pyridaly [46,47], insecticide coated liposome [48], neem oil [49], garlic essential oil [50], *Artemisia arborescens* essential oil [51], imidacloprid [52], thiamethoxam [53], carbofuran [54], thiram [55] and β -cyfluthrin [15], carbofuran [56], mancozeb [57], atrazine and simazine [41], oil-core silica-shell nanocapsule for fipronil [58], lansiumamide B [59].

Nanopesticide: Future Possibilities

Recent studies have shown that nano-pesticides have the capability to reduce toxic impact of chemical pesticide and provide target specific control of crop pest, can be helpful into development of intelligent nano systems for minimization of adverse problem to agriculture like environmental imbalance, food security and food productivity [60]. These nano system have shown great capability of controlled release pattern of active ingredient (AI) make them more efficient for long time period usability that can be solve eutrophication and residual pesticide accumulation problem. In addition, nanopesticide showed improved solubility and stabilities of active ingredient for effective control of pest [61]. Still, there is need to improve the techniques for significant contribution in agricultural practices, some aspects are identified by Fraceto et al. [60] in their review like

- a. Use of green chemistry and environmental sustainability principals in nanopesticide development to maximize their efficiency [41]
- b. Process development for up scaling of nanopesticide for commercial level
- c. Comparison of nano-formulation activity with pre-existing commercial product at field level to determine practical utility
- d. Environmental impact assessment of nanopesticide to determine toxicity level
- e. Improvement in regulation for nanomaterial application in agriculture.
- f. Development of smart nanopesticide will provide many solution to the agro-chemical industry i.e. solubility of active ingredient, stability, controlled release and targeted delivery of active ingredient but still lots of research is required to understand the fate of nanopesticide in environment.

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