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Nanopesticide: Current Status and Future Possibilities

Hemraj Chhipa*

The Energy and Resources Institute, India

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***Corresponding author:** Hemraj Chhipa, The Energy and Resources Institute, Darbari Seth Block, IHC Complex, Lodhi Road, New Delhi-110003, India, Fax: 011-24682100; Email: hrchhipa8@gmail.com

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 nanosesnsorto 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 effected of chitosan and copper to inhibit the fungal pathogen.

Different type of metal or their oxide were also exploredin 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 grater mortality against different pests like Sitophilus oryzae and Rhyzopertha 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 pyridalyl [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 toagriculture 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.

References

1. Peshin R, Dhawan AK (2009) Pimentel D Pesticides and pest controls. In: Integrated pest management: Innovation development process 1: 83-87.

2. Beard J, Sladden T, Morgan G, Berry G, Brooks L, et al. (2003) Health impacts of pesticide exposure in a cohort of outdoor workers. Environ Health Perspect 111(5): 724-730.
3. Guillette LJ, Iguchi T (2012) Life in a contaminated world. Science 337(6102): 1614-1615.
4. Mei C, Chang CH, Tao L, Lu C (2015) Residential exposure to pesticide during childhood and childhood cancers: a meta-analysis. Pediatrics 136(4): 719-729.
5. Naqqash MN, Gokce A, Bakhsh A, Salim M (2016) Insecticide resistance and its molecular basis in urban insect pests. Parasitology research 115(4): 1363-1373.
6. Khater HF (2012) Prospects of botanical biopesticides in insect pest management. Pharmacologia 3(12): 641-656.
7. Fareed M, Pathak MK, Bihari V, Kamal R, Srivastava, et al. (2013) Adverse respiratory health and hematological alterations among agricultural workers occupationally exposed to organophosphate pesticides. A crosssectional study in North India 8(7): e69755.
8. Gonzales JOW, Stefanazzi N, Murray AP, Ferrero AA, Fernandez BB (2015) Novel nanoinsecticides based on essential oils to control the German cockroach. J Pest Sci 88: 393-404.
9. Chhipa H, Kaushik N (2015) In: Conference Proceeding of symposium on recent advances in biotechnology for food and fuel. TERI, New Delhi, India.
10. Chhipa H and Joshi P (2016) Nanofertilisers, Nanopesticides and Nanosensors in Agriculture. In: Ranjan, Shivendu, Dasgupta, Nandita, Lichtfouse, et al. (Eds.), Nanoscience in Food and Agriculture. Springer, Germany, pp. 247-282.
11. Kah M, Hofmann T (2014) Nanopesticide research: current trends and future priorities. Environ Int 63: 224-235.
12. Kashyap PL, Xiang X, Heiden P (2015) Chitosan nanoparticle based delivery systems for sustainable agriculture. Int J Biol Macromol 77: 36-51.
13. Hwang IC, Kim TH, Bang SH, Kwon KK, Seo HR, et al. (2011) Effect of controlled release formulations of etofenprox based on nano-bio technique. J Fac Agric Kyushu Univ 56: 33-40.
14. Li M, Huang Q, Wu Y (2011) A novel chitosan-poly (lactide) copolymer and its submicron particles as imidacloprid carriers. Pest Manage Sci 67(7): 831-836.
15. Loha KM, Shakil NA, Kumar J, Singh MK, Srivastava C (2012) Bio-efficacy evaluation of nanoformulation of β-cyfluthrin against Callosobruchus maculatus (Coleoptera: Bruchidae). J Environ Sci Health 47(7): 687-691.
16. Petroski R J, Tellez MR, Behle RW (2005) Semiochemicals in pest and weed control: An introduction. In: Petroski RJ, Tellez MR, Behle RW (Eds.), Semiochemicals in pest and weed control. ACS Symposium Series 906, American Chemical Society, Washington, DC, USA, p. 1-7.
17. Bhan S, Mohan L, Srivastava CN (2014) Relative larvicidal potentiality of nano-encapsulated Temephos and Imidacloprid against Culex quinquefasciatus. Journal of Asia-Pacific Entomology 17(4): 787-791.
18. Campos EV, De Oliveira JL, Da Silva CM, Pascoli M, Pasquoto T, et al. (2015) Polymeric and solid lipid nanoparticles for sustained release of carbendazim and tebuconazole in agricultural applications. Sci Rep 5: 13809.
19. Oliveira JL, Campos EV, Gonçalves da Silva CM, Pasquoto T, Lima R, et al. (2015) Solid lipid nanoparticles co-loaded with simazine and atrazine: Preparation, characterization, and evaluation of herbicidal activity. J Agric Food Chem 63(2): 422-432.
20. Solanki P, Bhargava A, Chhipa H, Jain N, Panwar J (2015) Nano-fertilizers and their smart delivery system. In: Nanotechnologies in Food and Agriculture. pp. 81-101.
21. Yang FL, Li XG, Zhu F, Lei CL (2009) Structural characterization of nanoparticles loaded with garlic essential oil and their insecticidal activity against Triboliumcastaneum (Herbst) (Coleoptera: Tenebrionidae). J Agric Food Chem 57(21): 10156-10162.
22. Anton N, Benoit JP, Saulnier P (2008) Design and production of nanoparticles formulated from nano-emulsion templates-A review. J Control 128(3): 185-199.
23. Mason TG, Wilking JN, Meleson K, Chang CB, Graves SM (2006) Nanoemulsions: Formation, structure, and physical properties. J Phys Condens Matter 18(41): 635-666.
24. Wang LJ, Li XF, Zhang GY, Dong JF, Eastoe J (2007) Oil-in-water nanoemulsions for pesticide formulations. J Colloid Interface Sci 314: 230-235.
25. Anjali CH, Khan SS, Margulis-Goshen K, Magdassi S, Mukherjee A, et al. (2010) Formulation of water-dispersible nanopermethrin for larvicidal applications. Ecotoxicology and environmental safety 73(8): 1932-1936.
26. Anjali CH, Sharma Y, Mukherjee A, Chandrasekaran N (2012) Neem oil (Azadirachta indica) nanoemulsion-a potent larvicidal agent against Culex quinquefasciatus. Pest Manag Sci 68(2): 158-163.
27. Jiang LC, Basri M, Omar D, Rahman MB, Salleh AB, et al. (2012) Green nano-emulsion intervention for water-soluble glyphosate isopropylamine (IPA) formulations in controlling Eleusine indica (E. indica). Pesticide biochemistry and physiology 102(1): 19-29.
28. Lim CJ, Basri M, Omar D, Rahman MB, Salleh AB, et al. (2012) Physicochemical characterization and formation of glyphosate-laden nano-emulsion for herbicide formulation. Industrial Crops and Products 36(1): 607-613.
29. Díaz-Blancas V, Medina DI, Padilla-Ortega E, Bortolini-Zavala R, Olvera-Romero M, et al. (2016) Nanoemulsion Formulations of Fungicide Tebuconazole for Agricultural Applications. Molecules 21(10): 1271.
30. Bhagat D, Samanta K, Bhattacharya S (2013) Efficient management of fruit pests by pheromone nanogels. Scientific Reports 3: 1294.
31. Brunel F, El Gueddari NE, Moerschbacher BM (2013) Complexation of copper (II) with chitosan nanogels. Toward control of microbial growth. Carbohydr Polym 92(2): 1348-1356.
32. Sonkar SK, Roy M, Babar DG, Sarkar S (2012) Water soluble carbon nano-onions from wood wool as growth promoters for gram plants. Nanoscale 4(24):7670-7675.
33. Stadler T, Buteler M, Weaver DK (2010) Novel use of nanostructured alumina as an insecticide. Pest Manag Sci 66(6): 577-579.
34. Yildiz N, Pala A (2012) Effects of small-diameter silver nanoparticles on microbial load in cow milk. J Dairy Sci 95(3): 1119-1127.
35. Oliveira HC, Stolf-Moreira R, Martinez CBR, Grillo R, de Jesus MB, et al. (2015) Nanoencapsulation Enhances the Post-Emergence Herbicidal Activity of Atrazine against Mustard Plants. PLoS ONE 10(7): e0132971.
36. Song MR, Cui SM, Gao F, Liu YR, Fan CL, et al. (2012) Dispersible silica nanoparticles as carrier for enhanced bioactivity of chlorfenapyr. Journal of Pesticide Science 37(3): pp 258-60.
37. Liu F, Wen LX, Li ZZ, Yu W, Sun HY, et al. (2006) Porous hollow silica nanoparticles as controlled delivery system for water-soluble pesticide. Materials Research Bulletin 41(12): 2268-2275.
38. Qian K, Shi TY, Tang T, Zhang SL, Liu XL, et al. (2011) Preparation and characterization of nanosized calcium carbonate as controlled release pesticide carrier for validamycin against Rhizoctoniasolani. Microchimica Acta 173(1): 51-57.

39. Mondal KK, Mani C (2012) Investigation of the antibacterial properties of nanocopper against Xanthomonasaxonopodispv. punicae, the incitant of pomegranate bacterial blight. Annals of microbiology 62(2): 889-893.

40. Paret ML, Vallad GE, Averett DR, Jones JB, Olson SM (2013) Photocatalysis: effect of light-activated nanoscale formulations of TiO_2 on Xanthomonas perforans and control of bacterial spot of tomato. Phytopathology 103(3): 228-236.

41. Ocsoy I, Paret ML, Ocsoy MA, Kunwar S, Chen T, et al. (2013) Nanotechnology in plant disease management: DNA-directed silver nanoparticles on graphene oxide as an antibacterial against Xanthomonas perforans. Acs Nano 7(10): 8972-8980.

42. Buteler M, Sofie SW, Weaver DK, Driscoll D, Muretta J, et al. (2015) Development of nanoalumina dust as insecticide against Sitophilusoryzae and Rhyzoperthadominica. International Journal of Pest Management 61(1): 80-89.

43. Mishra S, Singh BR, Singh A (2014) Biofabricated silver nanoparticles act as a strong fungicide against Bipolarissorokiniana causing spot blotch disease in wheat. PLoS ONE 9(5): e97881.

44. Debnath N, Mitra S, Das S, Goswami A (2012) Synthesis of surface functionalized silica nanoparticles and their use as entomotoxicnanocides. Powder technology221: 252-256.

45. Saini P (2014) Residue studies of pyridalyl and its nanoformulation on vegetables. Ph.D. Thesis: Indian Agricultural Research Institute New Delhi, India.

46. Saini P, Gopal M, Kumar R, Srivastava C (2014) Development of pyridalylnanocapsule suspension for efficient management of tomato fruit and shoot borer (Helicoverpa armigera). Journal of Environmental Science and Health Part B, 49(5): 344-351.

47. Bang SH, Yu YM, Hwang IC, Park HJ (2009) Formation of size-controlled nano carrier systems by self-assembly. J Microencapsul 26(8): 722-733.

48. Adak T, Kumar J, Shakil NA, Walia S (2012) Development of controlled release formulations of imidacloprid employing novel nano-ranged amphiphilic polymers. J Environ Sci Health B 47(3): 217-225.

49. Sarkar DJ, Kumar J, Shakil NA, Walia S (2012) Release kinetics of controlled release formulations of thiamethoxam employing nano-ranged amphiphilic PEG and diacid based block polymers in soil. J Environ Sci Health A Tox Hazard Subst Environ Eng. Part A 47(11): 1701-1712.

50. Pankaj, Shakil NA, Kumar J, Singh MK, Singh K (2012) Bioefficacy evaluation of controlled release formulations based on amphiphilic nano-polymer of carbofuran against Meloidogyne incognita infecting tomato. J Environ Sci Health B 47(6): 520-528.

51. Kaushik P, Shakil NA, Kumar J, Singh MK, Singh MK, et al. (2013) Development of controlled release formulations of thiram employing amphiphilic polymers and their bioefficacy evaluation in seed quality enhancement studies. Journal of Environmental Science and Health 48(8): 677-685.

52. Chhipa H (2016) Nanofertilizers and nanopesticides for agriculture. Environmental Chemistry Letters: 1-8.

53. Wibowo D, Zhao CX, Peters BC, Middelberg AP (2014) Sustained release of fipronil insecticide in vitro and in vivo from biocompatible silica nanocapsules. J Agric Food Chem 62(52): 12504-12511.

54. Yin YH, Guo QM, Yun H, Wang LJ, Wan SQ (2012) Preparation, characterization and nematicidal activity of lansiumamide B nano-capsules. Journal of Integrative Agriculture 11(7): 1151-1158.

55. Fraceto LF, Grillo R, de Medeiros GA, Scognamiglio V, Rea G, Bartolucci C (2016) Nanotechnology in Agriculture: Which Innovation Potential Does It Have? Frontiers in Environmental Science 22.

56. Grillo R, Abhilash PC, Fraceto LF (2016) Nanotechnology applied to bio-encapsulation of pesticides. J Nanosci Nanotechnol 16(1): 1231-1234.

57. Amenta V, Aschberger K, Arena M, Bouwmeester H, Moniz FB, et al. (2015) Regulatory aspects of nanotechnology in the agri/feed/food sector in EU and non-EU countries. Regulatory Toxicology and Pharmacology 73(1): 463-476.

58. Gutierrez JM, Gonzalez C, Maestro A, Solé I, Pey CM (2008) Nano-emulsions: New applications and optimization of their preparation. Curr Opin Colloid Interface 13: 245-251.

59. Lai F, Wissing SA, Müller RH, Fadda AM (2006) Artemisia arborescens L essential oil-loaded solid lipid nanoparticles for potential agricultural application: preparation and characterization. Aaps Pharmscitech 7(1): E2.

60. Nuruzzaman M, Rahman MM, Liu Y, Naidu R (2016) Nanoencapsulation, nano-guard for pesticides: a new window for safe application. Journal of agricultural and food chemistry 64(7): 1447-1483.

61. Venugopal NV, Sainadh NV (2016) Novel Polymeric Nanoformulation of Mancozeb-An Eco-Friendly Nanomaterial. International Journal of Nanoscience 15(4): 1650016.

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