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Tiny Particles, Greater Impact of Nano-Bioformulation in Agriculture

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Abstract

Excessive usage of pesticides in agriculture has developed environmental and human health issues and they pose a threat on the non-targeted organisms. Despite the fact that natural source biopesticides are not, an environmentally clean-pest control is provided are usually constant and lead to increased application rates. Nanotechnology improves the transport, stability and controlled flow of nano-formulated pesticides. Green nano-bioformulations of plants or microorganism have the potential to become a developing area where crop protection could be made more sustainable by considering released controllable, higher rain fastness and low consumption of chemical resources which pose a challenge to green farming. A couple of questions arise, its limited availability, possible dangers connected to its use with safety and regulation. The combination of nanotechnology with biopesticides is revolutionizing and transforming the precision agriculture which makes the food to be secure and less environmental foot print.

Keywords: Bioformulation, Biopesticide, Emulsion, Nanocapsules

Introduction

The proliferation of the world reliance on the man-made pesticides with the intention of regulating the agricultural intensification has also been credited with a lot in ensuring the pest population and getting high crop yields. The United States, Brazil, China and India amongst others are the biggest users of the chemical in the world. The synthetic pesticides have been useful in the struggle against pest outbreak but the same is abused in the form of an overuse and at times even its rather careless use has raised a lot of issues regarding the environment as well as the health of the population. The remaining toxicants in the soil or in the water bodies could cause ecological imbalance together with the impact of toxic elements. Bioaccumulation and biomagnification in water ecosystems result in the food chain transfer of residues of pesticide products, which are a great threat to the non-target species (Vishnu *et al*., 2024). To mitigate these threats, more focus is given to less environmentally harmful options, bio-pesticides or nano-biotechnological advances.

Nanotechnology and Its Applications in Agriculture

The nanotechnology is an interdisciplinary technology that involves material and devices at nanoscale (<100 nanometers) and has evolved to be a strength of modern agriculture (Vishnu *et al*., 2024). Some areas in which nanotechnology aids in agriculture include revolutionary means of delivering, raising the effectiveness of the agrochemicals and potential observation of crop growth in real time. Nanopesticides, nanofertilizers and nanosensors have opened new nanomaterials that change the process of controlling the pest and nutrigation of the agriculturalist crops. The nanopesticides are specific to desire application of pesticide as small dosages of chemicals can be used and little environmental impact is involved. Nanofertilizers increase the ability to retain nutrients and crops and nanoparticles can make the plants tolerate abiotic stresses such as drought and salinity, making the soil healthier and microbiomes active. In addition, nanosensors play the key role within precision farming because in the changing climate, they will be able to detect the existence of initial symptoms of the lack of nutrients and the strike of pathogens to such a

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level that, as a result of well-timed intervention, sustainable agriculture and food security can be obtained. High quality surfactants prefer these preparations since they reduce the surface tension thus the increase in adhesion capacity and penetration of the plant surfaces. The other impact of this innovation is that besides improving on the performance on the active chemicals there is also the issue of controlled release thus reducing to a minimum the number of applications in the field. As a result, farmers will have the opportunity to use time and financial resources to the maximum and achieve a new height of environmental safety and the effectiveness of pest control (Vishnu *et al*., 2024).

Types of Nanoformulations (Vishnu *et al*., 2024)

1. Nanoemulsions: They occur in a quantitatively uniform form of small droplets of particles (usually oil to water and vice versa) that have been prepared using surface active agents and the high-energy method.

2. Nanoencapsulation: Nanoencapsulation is the method of encapsulation or entrapment of effective components with a shell or a matrix of nanometer scale. This method enables there to be controlled and prolonged release of agrochemicals and at the same time it limits premature degradation of the chemical before it reaches its purpose. It gives rise to effectiveness and increase the stability of the active compounds.

3. Nanosuspensions: These are the suspensions of solid particles matter less than one micron in diameter in a liquid. They enhance absorption and bioavailability of the types of poorly water-soluble substances by making them more soluble. The ease in mixing and dilutability of such formulations can be performed in order to apply these as foliar sprays.

4. Nanospheres: The active ingredients are distributed homogenously in a homogenous medium. They have the capacity to slowly and gradually liberate the pesticides or nutrients, making sure of continuous protection with time. The active compounds are also preserved by their stable structure which protects their degradation by the environment.

5. Nanocapsules: This type of core-shell involves an active component that is surrounded by a polymer shell. They promote the site-specific delivery and discharge control. Ideal as far as the solution of chemical wastes and off-target side effects.

6. Nanogels: Water soluble networks of hydrophilic polymers that get swollen in the water and are able to encapsulate the agrochemicals. They portray responsive discharge when exposed to specific environmental conditions. It can be applied to moisture sensitive or stress responsive agricultural practice.

Bioformulations

A mixture of various and useful microbial cultures, along with immobilized or ensnared plant extracts of any inert support agent which can be utilized, are handy in order to assist the growth of plants and suppress the pathogens of plants (Vishnu *et al*., 2024).

Nano-Bioformulations

The term nano-bioformulation implies development of nano-formulations with the help of biological entities mainly with reference to specific microbes due to the inherent ability of these microbes to synthesize inorganic material. The best of them should possess the best qualities including size and shape, least eco-toxicity and use of effective delivery. They possess nanoscale, which allows them penetrate further into the bodies of insects and this improves bio-efficacy. Enzyme denaturation can be as a result of oxidative stress, alteration of metabolic pathway or binding of some compounds with the constituents of the cell, resulting in decreased cellular activity and eventual death of the cell. The nano-bioformulations may also be classified as two types botanical and microbial on the basis of source of its occurrence. The composition method of the botanical based nano-bioformulations is prepared with the material on extracts, essential oils and phytochemicals of plants. These are natural substances that are altered to be nanoparticle so as to enhance the solubility, stability and bioavailability so as to be potent in agriculture. They are mostly used in controlling pests, growth and well-being of plants and immune-based disorders and are highly non-hazardous to non-fold organism due to the biodegradable and environment-friendly status (Vishnu *et al*., 2024). Developed azadirachtin-based nanocomposites biopesticide (260.9 nm) as a nanocomposite driven by nano-emulsification and freeze-dried with the help of whey protein isolate. It was better than bulk azadirachtin on *Spodoptera frugiperda* and proved to be significantly higher performance in LC_{50} values in the 11th day (Bae *et al*., 2022). In the same way, a garlic essential oil nanoemulsion (93.4 nm) was synthesized *via* the ultrasonic emulsification method to show a great acaricidal effect against *Aceria oleae* and *Tegolophus hassani* with LC_{50} values of 298.22 and 309.63 g ml^{-1}, respectively (Vishnu *et al*., 2024). In addition, rice moth was tested against the zinc, copper and silica nanoparticle that were green synthesized under spinach, tulasi and paddy husk. The most effective were silica nanoparticles (1500 ppm), zinc and copper which had superior effect to Malathion (Biradar *et al*., 2021).

Microbial based Nano-Bioformulations

Nano-bioformulations based on microbials refer to the utilization of bacteria, fungi or other organisms to synthesis nano-particles (Vishnu *et al*., 2024). B-NBPs are founded on the usage of useful bacteria or their components (as an example, *Bacillus thuringiensis* or *Bt*) in the treatment of insect pests particularly those of the lepidopterans. The insecticidal characteristic of *Bacillus* spore formed has brought about *Bt* (as well as other *Bacillus* species) to be vastly used microionizations formulations used *Bt* formulations are designed to improve dispersibility and efficacy *via* techniques of high-pressure homogenization and milling to lead or cause to an outcome or creation of superfine particles (250-500 nm) of *Bt*. The *Bt* nanocomposites are mixtures of *Bt* toxins and nanoparticles of metal oxides reinforcing the benefits of UV protection, stability and post-residual efficacy. Nanoemulsions, nanosuspension and the nanocapsules are able to enhance *Bt* to increase the stream control and the

action in the field. Bacteriogenic nanoparticles (BNPs) are produced either intra or extracellularly and come as a result of bacterial enzymes and metabolites. They are effective, non-toxic and are environmental-friendly methods of disease and pest management through which they exert their action by binding and inducing metal reduction and detoxification pathways with the use of BNPs.

Entomopathogenic Fungi based Nanoparticles

Entomopathogenic fungi are featured nanoparticle with the help of the functional biological agent like the common fungi, *etc.* (Vishnu *et al.*, 2024). The fungal proteins are said to act as the stable agents that renders the nanoparticles to be bioactive. It was even before the bacterial systems involving the biomass production that it was discovered that fungi is helpful. Sensitivities to strain surrounding conditions and consequently naked fungi is tolerable during large scale nano-particle production. Furthermore, size is also quite easy to manipulate and this is done by controlling growing conditions such as fungus altering metabolism. These nanoparticles in the insect body as it will get into its body through spiracles disseminate itself through trachea system. They enter directly into cells or become inside in form of endocytosis. When lysosomes or other organelles such as the mitochondria or the nuclei are destroyed, it is done through a channel that is cationic. This causes the degradation of DNA formation and the over-expression of reactive oxygen species (ROS) that free the pathways of apoptosis that is the release of cytochrome c and increased malondialdehyde (MDA) level as well as the imbalance in the proportion of the ratio between Bax and Bcl-2 ratio and caspase-3 activation. Effects of these are fatal to cell, tissue destruction and interruption of essential functions (Vishnu *et al.*, 2024). The synthesis of nanoparticles that were acquired in *Photorhabdus luminescens* supernatant cell-free was through spray an ultrasonic nozzle dryer. The nanoparticles produced significantly higher effects as a pesticide towards the cotton pests *i.e.*, *Tetranychus macfarlanei* and *Aphis gossypii* with the extremely low LC_{50} values of 0.0001 ppm and 0.0027 ppm (Kulkarni *et al.*, 2017). On the same, *Beauveria brongniartii* mediated zero-valent iron nanoparticles (Fe^0 NPs) were also found to be mediated was extremely against *Spodoptera litura*.

RNA based biopesticides offer very selective and low impact mechanism of pest management and this is through the killer of the harmful insects developing morphological or developmental deformities or death *via* RNA interference (RNAi). The RNAi is specific and non specific effects are inhibited with regards to the fact that RNAi occurs by sequence. Newer types of nanocarrier mediated RNAi delivery system have come to the limelight in green and sustainable agriculture. The merits of RNAi delivery on the conventional procedures are that it is very bioactive of low dose and is long acting. The xylem vessels and also the plant cell walls may also hinder the delivery of the double-stranded RNA (dsRNA). In order to mitigate them the technology of nanocarriers was developed which allows delivering RNA or DNA to get into the cell of the plant with a very high degree of specificity and achieve a transient or permanent silencing of the plant genes. A number of other nanocarrier-based RNA delivery strategies have been promising. Administration of dsRNA with nanoparticles of perylene imide, the method of population reduction in *Aphis glycines* will be 80.5% and of gene interference would be 95.4%, which proves the chance of such a modality and its usage in achieving effective pest control (Zheng *et al.*, 2019).

Limitations of Nano-Bioformulations

In addition to the possibility of their usage to be more powerful and nano-biopesticides raise a number of issues as non-toxic alternatives to chemical pesticides (Vishnu *et al*., 2024).

- *Poor Commercial Viability*: The production is too small to be used in a broad sense hence it can only be used in a few sectors.
- *Little Rain Fastness*: Nano-biopesticides are washed away (by rain/irrigation) and hence they must be used with a high degree of frequency compared to conventional pesticides.
- *Safety*: Its improper use may be a danger to the human and the surrounding. Nanoparticles of very small sizes are able to penetrate the skin or accumulate in the environment that impact on the wildlife.
- *Potential Development of Resistance*: The possibility of pesticide resistance exists in case of misuse as it is the case with conventional pesticides overuse.

Conclusion

The prospect of combining nanotechnology and biopesticides is revolutionising agriculture making the use of more accurate and effective in the fight against crop pests. The nanoscale formulation of botanical and microbial pesticides are selective and have environmentally friendly products which cause less environmental burden as well as reduced use of chemicals. The strategy facilitates the pinnacle agricultural practice, enhances agricultural sustainability and promotes food security. Following increasing demand of sustainable answers, the future of successful and sustainable ways of management of pests appears the nano-bioformulations.

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