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Nanotechnology for Crop Protection Possibilities and Challenges

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Introduction

Nanotechnology refers to the study and design of any material that exhibits at least one of its dimensions in the nanometer range i.e. 1-100 nm. Based on its dimensions, nanoparticles can be classified into three groups, materials whose one dimension is in the nano range (e.g. nanowire, nanotubes, nanorods); materials whose two dimensions are in the nano range (e.g. graphenes, nanofilms) and materials which exhibit nano range in all the three dimensions (e.g. quantum dots). Due to its groundbreaking innovations nanotechnology has left no field untouched and crop protection is no exception. Nanoparticles may exhibit completely different properties as compared to their bulk form. This can be understood by a simple example of gold which is highly inert in its bulk form whereas gold nanoparticles exhibit high reactivity. Nanoparticles owe such unique properties primarily due to their very high surface to mass ratio. Nearly 60% of the population in developing countries rely on agriculture for their livelihood. Food safety can be ensured for the ever-increasing population through two ways: the first one is by increasing the overall agricultural production and secondly through protection of the current agriculture produce from various pests during pre and post-harvest operations. The following article focuses on the role of nanotechnology in achieving the second objective.

Applications of Nanotechnology in Crop Protection

Nanomaterials as carrier for slow release of agrochemicals

It is a well-known fact that most of the plant protection chemicals remain unutilized and lost to the environment in various ways after their application on different crops. These losses can be checked through the controlled release mechanism for agrochemical delivery. The use of nanocarriers for agrochemicals delivery allows the plant to use the plant protection chemical rationally. This enables the user to achieve effective pest management with the minimum use of agrochemicals. In the conventional formulations, a high concentration of active ingredient (a.i.) remains available at the initial stage of application which reduces at a very fast rate due to various abiotic and biotic losses whereas, in the slow-release formulations, the carrier is optimized in such a way that it releases the a.i. just above the effective level. This leads to numerous benefits that include a reduction in production cost for farmers, less pesticide load on the environment, less frequent application of pesticides, and longer period of pest management through a single application.

Poly(ethylene glycol) based amphiphilic polymers aggregate in an aqueous medium to form nano-micelles that can be utilized to encapsulate the pesticide a.i . This type of slow-release pesticide carrier is effective especially for the highly volatile active ingredients like essential oils, pheromones, etc.

Nanopesticides

Nanopesticides refer to the pesticide formulations where the size of a.i. is in the nano range (i.e. 1-100 nm). Nano pesticide can be of organic (chemical pesticide e.g. hexaconazole) as well as inorganic nature (metallic nanoparticles). The application of nanosized sulphur, so developed, has shown improvement in the fungicidal potential of sulphur particles and is nearly two times more effective than the commercial formulation thereby allowing optimum control of pest at lower application levels. Similarly, developed nanohexaconazole is 2-6 times more active than the commercial formulation against different *Rhizoctonia solani* isolates without causing any adverse effects to the germination and establishment of mustard seeds. Metallic nanoparticles such as silver nanoparticles interact with cell membranes and are widely known for their high reactivity and destabilizing effects on bacterial and fungal cell membranes, hence can be explored in the management of plant diseases. Silica nanoparticles have also been explored by many researchers for insect pest management. Nanosilica, when applied on the leaves and stem surface, is absorbed by the insect's cuticular lipids leading to the death of the insect caused by desiccation.

Intelligent nanosensors

Nanosensors are ingenious tools that can be used for the diagnosis and detection of insect and disease-causing pathogen. Moreover, these sensors can also be explored to detect the pesticide residues in the soil-plant system thereby helping to keep the pesticide residue in agricultural produce up to the permitted levels only. These nanosensors provide a large reaction surface area, leading to a rapid reaction response because of increased sensitivity to detect signals. This property makes them even more efficient than commonly available techniques. The use of nanosensors or biosensors can be advantageous and lead to the improvement of agricultural precision to the next level in future. Fluorescent silica nanoparticles combined with antibody molecules can be helpful in detecting the plant pathogen like *Xanthomonas axonopodis* pv. *Vesicatoria*, responsible for causing bacterial spot disease in tomatoes.

Limitations in Adaptation of Nanotechnology for Crop Protection

The major limitation for fast adaptation of nanotechnology is that the property of nanoparticles may be altogether different from its bulk form. Therefore, it becomes necessary to evaluate their effects on humans, the environment, and other non-target organisms before introducing them in the public domain. Moreover, as the production of nanotechnology-based plant protection products is low so in the present situation, it involves high production cost and thus making the final product costlier for the end-users. Also, the guidelines for the use and production of nanoproducts are very scarce even in the developed nations hence urgent formulation and implementation of guidelines on different aspects related to these products is required. It will not only encourage the researchers to explore the possibilities related to the development and evaluation of nanoproducts at large scale but also reduce their production cost if commercialized.

Conclusion

The application of nanotechnology in plant protection is advancing because of its potential benefits that can lead to a reduction in the losses due to pests along with the enhancement in the quality and quantity of the crops. To increase the acceptance of environment-friendly nanotechnologies, the prime need is to quantify the safe doses of nanoparticles that have not been defined yet in most of the cases. This can be achieved by conducting more and more trans-generational studies including long term effects by *in situ* field trials. It must be kept in mind while conducting such studies that each study should be condition-specific and generalization regarding the effect of nanomaterials on crops, non-target organisms and the environment must be avoided.