Nanotechnology in pesticide formulation: A new era in plant protection

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Nanotechnology is any engineered materials, structures, systems and process which exist or operate at a scale of 100 nm or less (1 nm=10^{-9}m). With the development of improved systems for monitoring environmental conditions and delivering pesticides appropriately, nanotechnology can further improve our understanding of the biology of different crops and thus potentially enhance yields. It can offer routes to plant disease diagnostics, insect-pest management and efficient pesticides utilization[1]. Nanostructure catalysts will help in increasing the efficiency of pesticides allowing lower doses to be used. The environmental problems caused by overuse of agrochemicals have attracted lot of attention of scientists in the recent years due to high toxicity and non-biodegradability of pesticides and lack of scientific pesticide formulations. Techniques at the nano-scale are being applied in an attempt to enable the targeted delivery or increased toxicity of pesticide applications. This includes insertion of nano-scale active ingredients into pesticides. The specific properties of these nano-scale materials, such as their ability to dissolve in water more effectively than the existing products or their increased stability, are designed to maximize the effectiveness of these pesticides. There are different types of nano formulations that can be used for agrochemicals like nano emulsions, nano encapsulations, nano suspensions and others.

Nano-emulsions are water or oil-based, contain uniform suspensions of pesticidal nanoparticles, have many potential applications as disease and pest prevention measures. They exhibit greater stability and increased coating of leaves and uptake through plant cell walls, as a result of low surface tension[2]. The main advantages are solubilisation of hydrophobic pesticides (hence, no need for toxic organic solvents), no precipitation or creaming (therefore, no need for constant mixing), increased stability (protect against oxidation) and improved uptake. Nano-emulsions can be used for hydrophilic and hydrophobic pesticides, but are largely being developed for those that are poorly water soluble. Different pyrethroids such as cyhalothrin and cypermethrin have been successfully formulated as lipid nano-emulsion, obviating the need for organic solvents such as C_6H_6 $C_6H_5CH_3$. Nano-emulsion particles are thermodynamically driven to fuse with lipid containing organisms. This fusion is enhanced by cationic charge of the emulsion and anionic charge on the pathogen. When enough nano particles fuse with the pathogen, they release a part of energy entrapped in the emulsion. Both the active ingredient and the energy released destabilize the pathogen lipid membrane, resulting in cell lysis and death.

Nano-encapsulation techniques enable greater control over the circumstances in which encapsulated pesticides will be released. Pesticides could be released quickly or slowly depending on need and under specific conditions, such as moisture and temperature. Such nano-encapsulation techniques not only provide in-built pesticides for crops but also in built switches to control the release and subsequent availability of pesticides[3]. Nano-encapsulated pesticides meet these demands in that they enable smaller quantities of the pesticides to be used effectively over a given period of time interval and in that their design enables them to resist the severe environmental processes that act to eliminate conventionally applied pesticides, *i.e.* leaching, evaporation and photolytic, hydrolytic and microbial degradation.

Nanosuspensions consist of the pure poorly water-soluble pesticide without any matrix material suspended in dispersion. It is submicron colloidal dispersion of pure particles of pesticide stabilized by surfactants. By formulating nanosuspensions problems associated with delivery of poorly water soluble pesticide and lipid-soluble pesticides can be solved. Preparing nanosuspensions is preferred for the compounds that are insoluble in water (but are soluble in oil) with high log P value. Conventionally, the pesticides that are insoluble in water but soluble in oil phase system are formulated in liposome, emulsion systems but these lipidic formulation approaches are not applicable to all pesticides. In these cases nanosuspensions are preferred. In case of pesticides that are insoluble in both water and in organic media instead of using lipidic systems nanosuspensions are used as a formulation approach.

Agrochemicals companies are reducing the particle size of existing chemical emulsions to the nanoscale, or are encapsulating active ingredients in nanocapsules designed to break open in certain conditions in an alkaline conditions in an insect’s stomach. Similar to the nanocapsules and nanoemulsions being developed for the food and packaging sectors, the smaller size of nanoparticles and emulsions used in agrochemicals is intended to make them more potent[4]. Leading agrochemicals companies are engaged in nanotech research. Agrochemical company, currently retail a number of chemicals with emulsions that contain nanoparticles, *e.g.*, ‘Primo MAXX Plant Growth Regulator’, ‘Banner MAXX Fungicide’, ‘Apron MAXX RFC seed treatment’ and ‘Cruise MAXX Beans’. Primo MAXX ® plant growth regulator, if applied prior to the onset of stress such as heat, drought, disease or traffic can strengthen the physical structure and allow it to withstand ongoing stresses throughout the growing season. Another encapsulated product marketed under the name Karate ® ZEON, is a quick release microcapsulated product containing the active compound lambda-cyhalothrin (a synthetic insecticide based on the structure of natural pyrethrins) which break open on contact with leaves. In contrast, the encapsulated product "gutbuster" only breaks open to release its contents when it comes into contact with alkaline environments, such as the stomach of certain insects[5,6]. Environmental exposure varies on the basis of condition such as the way in which materials are handled in the workplace, how nanomaterials partition to various phases (*e.g.*, water and air), mobility of nanomaterials in each of these phases, their persistence, and the magnitude of the sources. What is also needed is an evaluation of the expected quantities and concentrations of NP in environmental systems. To date nothing is known about this issue, neither from an analytical point of view (*e.g.*, actual measurements of NP in the environment) nor with respect to theoretical or modeling studies. As a starting point to risk assessment, exploring the sources and environmental pathways helps to identify relevant applications and situations where a subject deserving protection may face exposure to nanotechnology[7]. Although several approaches have been undertaken to develop nanoformulations of agrochemicals around the world, but research on molecular mechanism of action of nano pesticides in insects, biosafety and molecular interaction with plant, soil and environment is scanty. When the nano formulations are applied as foliar spray or in the soil, the carrier and pesticide interact with the soil, insect, plant and atmosphere[8]. It is not completely clear how these nano encapsulated chemicals are degraded in the soil and environment.

References

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