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Nanotechnology : An opportunistic tool in plant protection

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Agriculture is the backbone of most developing countries. With the development of improve systems for monitoring environmental conditions and delivering pesticides appropriately, nanotechnology can improve our understanding of the biology of different crops and thus potentially enhance yields or nutritional values. In addition, it can offer routes to add value in crops or environmental remediation and also likely to revolutionize the next stage of development of genetically modified crops and plant breeding, molecular nanotechnology, plant disease diagnostics, efficient fertilizers & chemicals pesticides, post-harvest technology, soil management, water purification, animal production inputs, and precision farming techniques. Some nano-agrochemicals are already in use; however other applications are still in their infancy stages. Nano-structured catalysts will help in increasing the efficiency of pesticides and herbicides, allowing lower doses to be used. Nanotechnology will also protect the environment indirectly through the use of renewable energy supplies, and filters or catalysts to reduce existing pollution. Microbes through nanotechnology are being exploited as eco-friendly factories and viable alternatives to the physical and chemical methods of cleaning. Research has shown that alfalfa plants are grown in gold rich soil absorb gold nano-particles through their roots and accumulated nano-particles can be mechanically separated from the plant tissue following harvest.

The environmental problems caused by overuse of the agrochemicals, particularly the pesticides, have attracted a lot of attention of scientists in recent years engaged in basic research. Techniques at the nano-scale are also being applied in an attempt to enable the targeted delivery or increased toxicity of pesticide applications. This includes the 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 existing products or their increased stability, are designed to maximize the effectiveness of these pesticides. Recent research producing crystals in the nano-size range has provided evidence of improved efficiency.

There are several nano-plant protection chemicals available in the market such as nano-emulsions, nano-encapsulations, nano-suspensions. Nano-emulsions contain uniform suspensions of pesticidal or herbicidal nano-particles, have many potential applications as disease and pest prevention measures. Nano-emulsion exhibit greater stability and increased coating of leaves and uptake through plant cell walls, as a result of low surface tension. The encapsulation techniques of nanotechnology enable greater control over the circumstances in which encapsulated pesticides will be released. Nano-encapsulated pesticides meet the demands in which 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, photolytic, hydrolytic and microbial degradation. Research is ongoing to make fertilizer and pesticide delivery systems which can respond to environmental changes. The ultimate aim is to make the plants use water, pesticides and fertilizers more efficiently, to reduce pollution and to make agriculture more environmentally friendly. Nano-suspensions consist of the pure poorly water-soluble pesticide without any matrix material suspended in dispersion. By formulating nano-suspensions problems associated with delivery of poorly water-soluble pesticide and lipid-soluble pesticides can be solved. Preparing nano-suspensions is preferred for the compounds that are insoluble in water (but are soluble in oil) with high log P value.

Some of the first nano-agrochemicals in development are nano-reformulations of existing pesticides, fungicides, for plant, soil and seed treatments. Agrochemicals companies are reducing the particle size of existing chemical emulsions to the nano-scale, or are encapsulating active ingredients in nano-capsules designed to break open in certain conditions in an alkaline conditions in an insect's stomach. Similar to the nano-capsules and nano-emulsions being developed for the food and packaging sectors, the smaller size of nano-particles and emulsions used in agrochemicals is intended to make them more potent. Leading agrochemical companies such as BASF, Bayer Crop Science, Monsanto and Syngenta are engaged in nanotechnology research. In terms of commercial applications of this technology, Syngenta, the world's largest agrochemical company, currently retail a number of chemicals with emulsions that contain nano-particles, 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 from Syngenta delivers a broad control spectrum on primary and secondary insects' pests of cotton, rice, peanuts and soybeans, marketed under the name Karate ® ZEON. This is a quick release micro-capsulated product containing the active compound lambda-cyhalothrin (a synthetic insecticide based on the structure of natural pyrithrins) which break open on contact with leaves.

Nanotechnology has extremely high potential tool in agriculture particularly used for rapid detection techniques, biosensor related control of pest and disease, soil management etc. Although several approaches have been undertaken to develop nano-formulations of agrochemicals around the world, but research on molecular mechanism of action of nano pesticides in insects, bio-safety 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. It is not completely clear how these nano encapsulated chemicals are degraded in the soil and environment.

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