Use of Nanoparticles in Plant Disease Management

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Plant diseases and pests cause the loss of 20 % to 40 % of crops annually. Toxic pesticides that could endanger both humans and the environment are the mainstay of current plant disease management. In comparison to conventional pesticides, nanotechnology can reduce toxicity, extend the shelf life, and increase the solubility of pesticides that are poorly soluble in water. These benefits could have a favourable effect on the environment. The two ways that nanoparticles can be used to manage plant diseases are examined in this review: either as nanoparticles on their own, serving as protestants, or as nanocarriers delivering RNA-interference compounds, fungicides, insecticides, and herbicides. Although using nanoparticles has a number of potential benefits, few products using nanoparticles have been released for use in agriculture. There exist multiple explanations for the dearth of commercial uses.

Introduction

The study of the synthesis and uses of biomaterials with sizes ranging from one to 100 nanometers is known as nanotechnology. The two biggest risks to any nation's economy are insects and pests, which can seriously harm crops and result in significant losses. Regular use of pesticides and insecticides has led to environmental contamination, the buildup of residues in produce, and the development of pest and disease resistance. Therefore, different methods of controlling infections and pests are required. Nanotechnology provides fresh perspectives on agriculture and biotechnology. There are currently several limitations with nanotechnology-based plant protection systems. First off, not enough research has been done on the possible toxicity of some nanomaterials (such as nano silver, nano gold, etc.) to plants, animals, and the environment. It is possible for nanomaterials to build up in the tissues of plants and animals and enter the food chain. However, this risk is eliminated by using non-toxic materials (such as starch, chitin, or nano clays instead of metals). This article addresses the uses of various nanoparticles in the control of plant diseases as well as how they work to combat bacteria. The creation of nanoparticles (NPs) by the use of biomolecules such as DNA, proteins, enzymes, and plant extracts has created new opportunities for green nano biotechnology research. They have shown to be economical, environmentally benign, and effective against microorganisms. Some of the methods by which nanomaterials used to kill bacteria work include ATP depletion, DNA destruction, lipid peroxidation, protein oxidation, and the formation of reactive oxygen species. Two methods exist for using nanoparticles to protect plants: (a) the nanoparticles themselves offer crop protection, or (b) the nanoparticles act as carriers for pesticides already in use or other actives, like double stranded RNA (dsRNA), and can be sprayed on seeds, foliar tissue, or roots. As carriers, nanoparticles can offer a number of advantages, including (i) increased shelf-life, (ii) better solubility of pesticides that aren't very soluble in water, (iii) decreased toxicity, and (iv) more site-specific uptake into the intended pest. An enhancement in the activity and stability of the nanopesticides against environmental stresses (sunlight and rain) is another potential advantage of nanocarriers. This might lead to a major decrease in the number of applications, which would lower their toxicity and lower their costs.

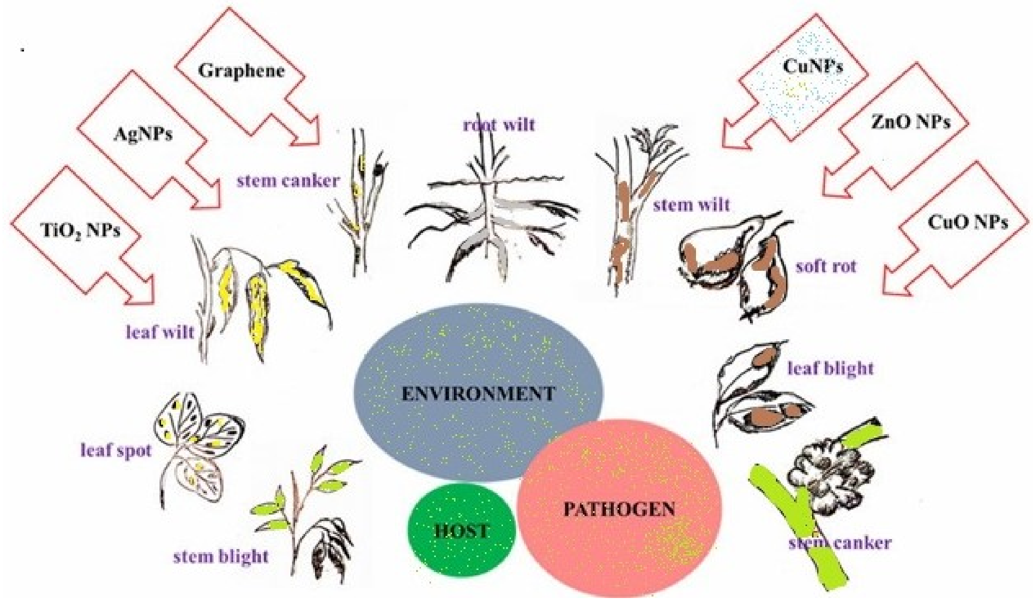

Fig.1. Antimicrobial nanoparticles to achieve disease control in disease triangle, common disease symptoms in plants (Rajwade *et al*., 2020)

Application of nanoparticles

The use of nanotechnology in crop protection has great potential for managing pests and diseases through the targeted and controlled application of agrochemicals as well as the provision of diagnostic instruments for early identification. As "magic bullets," nanoparticles can carry genes, herbicides, or nanopesticides that target particular plant cellular organelles and unleash their contents. Because they are not broken down by outside forces or the crop plant itself and because they do not unintentionally disperse into the soil, highly stable and biodegradable active compounds enclosed in capsules known as nanoparticles allow for the use of fewer active compounds for plant treatments, thereby reducing their environmental impact.

Reducing the need of plant protection chemicals, minimizing nutrient losses during fertilization, and increasing yields through optimal nutrient management are the main goals of applying nanomaterials in agriculture. In contrast to other industries applying nanotechnology, the agriculture industry is still somewhat marginal and hasn't made a significant impact on the market despite these prospective benefits. The diagnosis and treatment of diseases, improving plant nutrition uptake, delivering active chemicals to targeted locations, and water treatment procedures are just a few applications for nanotechnology tools and devices, such as nanocapsules, nanoparticles, and even viral capsids.

The quantity of chemicals released into the environment and the harm done to non-target plant tissues can both be decreased by using target-specific nanoparticles. Genetic modification and plant breeding are two other fields that investigate gadgets created from nanotechnology. Although nanotechnology has a lot of potential for use in agriculture, there are still certain challenges that need to be resolved, like scaling up production processes and cutting costs, as well as problems with risk assessment. In this regard, nanoparticles made of biopolymers such as proteins and carbohydrates that have no effect on the environment or human health are especially appealing. For example, a lot of research is being done on the possibility of using starch-based nanoparticles as sustainable and nontoxic agrochemical and bio-stimulant delivery methods.

Recently, highly sensitive bio-chemical sensors have been produced using nanomaterials and nanostructures with special chemical, physical, and mechanical capabilities (such as electrochemically active carbon nanotubes, nanofibers, and fullerenes). These nanosensors have important ramifications for agricultural applications as well, including for soil analysis, simple biochemical detection and control, water management and delivery and the administration of pesticides and nutrients.

In addition to having better qualities than conventional micro and macro composite materials, nano composites made of biomaterials are also produced in a more environmentally friendly manner. Nowadays, a wide range of production techniques are being developed to create valuable Nano composites from traditionally obtained resources. Applications of nanotechnology for commercial purposes in agriculture: From a business standpoint, established agrochemical companies are looking into the possibilities of nanotechnologies, specifically whether purposefully produced active ingredients with nanoscale sizes can increase the effectiveness or penetration of beneficial components in plants.

The hunt is currently underway for effective disease management techniques that won't harm the environment or upset the equilibrium of the natural biota. The application of nanoparticles in agriculture to control illness is one tactic for this. This paper provides an overview of the different ways that nanoparticles can help crops become resistant to disease, as well as the potential use of nanoparticles as genetic material carriers to create crops that are resistant to disease. Pathogen control is achieved directly through the use of nanoparticles. Antiviral, antifungal, and antibacterial properties have been used to nanoparticles. Future research on the nano-encapsulation of pesticides in controlled release matrices is highly promising. It has been demonstrated that nano-encapsulation improves pesticide effectiveness, lowers volatilization, and lessens toxicity and environmental contamination in crops. Agrochemicals or biomolecules contained in nanoparticles can be designed to release in a targeted and regulated way. The topic of transgenic pathogen resistance presents significant opportunities for nanoparticles as well. The use of nanoparticles to provide crops disease resistance has the potential to transform the agricultural industry. There are countless options in this field because it is so adaptable. Numerous researchers have demonstrated how nanoparticles affect plant growth and accumulate in food sources in recent years. Plant metabolism is being impacted by metal and metal oxide nanoparticles. The effects of nanoparticles on plants in terms of size, concentration, and exposure protocol are covered in this chapter. In pest control systems, nanoparticles can be employed as nanopesticides, medicine delivery vehicles, or pesticide carriers. By destroying microorganisms or triggering plant defence mechanisms, nanoparticles help plants resist disease. Excellent virucidal qualities against a variety of plant viruses have been demonstrated by antiviral assay of distinct NPs. NPs' long term effects and fate on humans, plants, soil microbiota, and the ecosystem have been questioned. NPs affect plants in ways that are both advantageous and detrimental. The important studies conducted to treat plant viral infections are covered in this overview. A picture of the issue has been created by compiling the results of the application of nanomaterials such as silver, gold, zinc, copper, magnesium, nickel, silica, and bio-compounds to control the virus. The advantages of nanotechnology in controlling plant virus diseases as well as its negative effects on the environment will be covered in this conversation.

Nanotechnology: Scope for controlling pathogen

Less than 0.1% of the pesticide is said to reach the sites of action due to airborne loss during application, runoff, spray drift, off-target deposition, and photo-degradation, which all have an impact on the environment and application costs (Pimentel,1995; Castro *et al.,* 2013). There is an urgent need to reduce the excessive use of pesticides and fertilizers by developing better alternatives, as the demand for pesticides to manage diseases and pests grows globally. If used appropriately, nanotechnology has the potential to completely transform civilization and has a wide range of applications in the fields of agriculture, medicine, and the food industry. Controlled release of encapsulated pesticides, fertilizers, and other agrochemicals to protect against pests and pathogens is one potential use of nanotechnology in crop protection. By employing nanosensors, it is also helpful in the early detection of contaminants, such as pesticide residues, and plant diseases (Ghormade *et al.,* 2011; Lin *et al.,* 2020).Utilizing nanoparticles for crop protection aids in the creation of effective and promising methods for controlling plant diseases.

Nanoparticles for disease management

Hydrophilic, biocompatible, and extremely stable, inorganic nanoparticles are non-toxic. Inorganic nanoparticles can include silver, zinc oxide, iron oxide, calcium phosphate, gold, and iron oxide, among other materials (Paul and Sharma 2010; Kurtjak *et al.,* 2017). Ions included in inorganic nanoparticles have antibacterial properties. Reactive oxygen species (ROS) are produced by zinc and copper, which destroy the pathogen that has absorbed them. At low concentrations, gold and silver are extremely poisonous to bacteria. Pathogen cell membranes are disrupted by the use of nanoparticles. ROS, free radicals, and metal ions are also produced when nanoparticles are applied. Furthermore, extremely tiny nanoparticles also intercalate into the DNA. It's well knowledge that metals can bind to biological proteins' amine or thiol moieties, deactivating and precipitating the protein. Proteins' strong affinity for metal ions causes cellular concentrations to rise, which ultimately results in cell death (Mittapally *et al.,* 2018). Polymeric nanoparticles (PNPs) are made of different natural or synthetic polymers and are utilized in the synthesis of nano-capsules or nanospheres. Numerous of these polymers are non-toxic and biodegradable (Stanisic *et al.,* 2018).

Conclusion

Nanotechnology has the ability to transform current pest management technologies and offer solutions for agricultural applications. The creation of nanopesticides has the potential to yield previously unheard-of benefits, such as: (i) improved solubility of poorly water soluble pesticides; (ii) increased bioavailability and efficacy of pesticides when loaded onto nanoparticles and reduced pesticide toxicity; (iii) enhanced shelf-life and controlled delivery of actives; (iv) target specific delivery of the active molecules and pH dependent release; (v) intelligent delivery of RNAi molecules for the management of disease; (vi) nanoparticles as carriers to slow down the degradation of active molecules and improve the formulations' UV stability and rain fastness; and (vii) nanopesticides to improve the selective toxicity and defeat pesticide resistance.