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Short Communication

Nanobiofungicides: is it the Next-Generation of Fungicides?

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Introduction

Worldwide insect caused an estimated 14% loss, plant diseases cause a 13% loss and weeds a 13% loss. The value of plant diseases loss was calculated to be about 2,000 billion dollars per year[1]. Phytopathogenic fungi comprises an important group of plant pathogens that cause approximately $45 billion in crop losses every year in all over the world.

Plant pathogens are able to contaminate any plant tissue at different stages of crop growth[2]. For instance, the fungal pathogens, such as *Rhizoctonia solani, Fusarium* spp., *Phytophora* spp., are able to attack the aerial and soil parts of plants, while *Botrytis cinerea* is able to infect green and fruit tissues in over 200 plant cultivars, and is also responsible for significant damage caused to fruit during distribution and storage. *B. cinerea* alone is responsible for 10% of the worldwide fungicide market, representing more than €500 million[1]. Conventional methods to control plant pathogens and pests have affected both the environment and economy of farmers as 90% of the applied fungicides can lost in the open field during application and as overland flow, affecting both the agricultural and environment and increasing application costs to the farmer. Thus, the environmental problems caused by overuse of pesticides have been the matter of concern for both scientists and public. About 2.5 million tons of pesticides are used on crops each year and the universal harm caused by pesticides reaches $100 billion annually[1]. The reasons for this are dual: (1) the high toxicity and nonbiodegradable properties of pesticides and (2) the excessive pesticide residues in soil, water resources and crops that have an effect on human, and animal health[3]. The use of nanotechnology to develop fungicides is still mostly unknown and in the early stages. Development of alternative eco-safe antifungal agents like bio-based nanomaterials is urgently needed. To fight against fungal pathogens, replacing the poisonous elements like heavy metals. The expression nanofungicides is used to describe any fungicide formulation that (a) intentionally includes entities in the nanometer size range up to 100 nm, (b) is designated with a "nano"prefix (*e.g.*, nanohybrid , nanocomposite), and/or (c) is claimed to have novel properties associated with the small size. On this basis, nanofungicides include a wide variety of products which are described in detail consequently[4]. Several formulation types of nanopesticides including: organic ingredients (*e.g.*, active ingredient(s), polymer-based inorganic silica-based nanoparticles and titanium dioxide, nanoemulsions and nanoclays in various forms (*e.g.*, particles, micelles)[5]. Nevertheless, before a broad-spectrum use of nanotechnology-based products in plant protection, non-targeted effects should be evaluted and public concern should be considered. Remote activation and monitoring of intelligent nano-delivery systems can assist agricultural growers of the future to minimize fungicides and pesticides use. Intelligent use of chemicals on the nano scale can be a suitable solution for this problem. These materials are used into the part of plant that was attacked by disease or pest. Also these carriers in nano scale have self-regulation, this means that the medication on the required amount only be delivered into plant tissue.

Discussion

Nanotechnological application in plant pathology is still in the early stages. More nanophytopathological studies on physiology of host and pathogen, interaction, infection process and disease diagnosis will help in developing new nanopesticides that are less harmful to the environment than conventional formulations[6]. Updated literatures confirmed that metal nanoparticles are an effective nanocides against plant fungal pathogens[7-8]. For example, an eco-friendly fungicide is under development that use nanomaterials to liberate its pathogen killing properties only when it is inside the targeted fungal pathogen[9]. Since the early 1930s copper nanoparticles dissolved in water have been used as a fungicide for controlling grapes and fruit trees diseases[10]. Recently, *in vitro* assays conducted by

Krishnaraj et al[11] and Gopinath and Velusamy[12] showed the strong inhibitory effects of biosynthesized AgNPs against various fungal diseases[13]. The green bsAgNPs exhibited strong antifungal activity against *Bipolaris sorokiniana* and effectively controlled its infection in wheat plants[14]. Replacement of synthetic fungicides by generally recognized as safe (GRAS) subestances, which are non-toxic for consumers and for the environment, is gaining considerable attention. The bioactive natural products including, plant extracts and essential oils have been reported to control plant diseases, both *in vitro* and *in vivo*[15]. GRAS salts have been shown to be active antimicrobial agents against a range of plant pathogenic fungi[16].

The bonding between safe antimicrobial agents such as biocontrol agents, GRAS subestances, essential oil, biopolymer and curpic, and sulfur NPs could result in synergistic effect. The effect of combination between different active ingredients may increase antimicrobial activity, reduce pesticide usage and delay the development of fungal resistance. The antimicrobial activities of the inorganic nanoparticles such as S, Ag, CuO, MgO and ZnO were investigated separately[7] or combined with biopolymer in previous studies[7].

Active ingridents combination also provides the feasibility to reduce the fungicide residue due to the solar radiation activity. Thus, it encouraged us to set up a new green nanocide which management fungal pathogen using a synergistic antimicrobial activity and successive photocatalytic degrade pesticide residue to protect plant proficiently and eco-friendly. Such aims led us to focus on cupric nanoparticles which are low-cost, stable[7,17], sensitive to pathogen fungi[18-19]. Nanobiocide a product prepared by mixing several bio-based chemicals was reported to eliminate fungus *Magnaporthe grisea*, the causal agent of rice blast disease[20].

Few researchers have studied the combined antimicrobial effect of inorganic NPs with bioorganic pesticides in the field of plant protection, let alone demonstrated synergistic effect[21-22]. The effect of combination between different active ingredients may increase antimicrobial activity, reduce pesticide usage and delay the development of fungal resistance[23-24]. Ecofriendly hybird nanofungicides enable smaller quantities of the fungicides 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, chemical hydrolysis and biodegradation. Chitosan and Cu-chitosan nanoparticles proved their uniform size and stability, which may contribute to their higher antifungal activity against *Alternaria alternata, Macrophomina phaseolina* and *Rhizoctonia* in *in vitro* studies. Cu-chitosan nanoparticles also showed maximum inhibition rate of spore germination of *A. alternata*. Compared to chitosan and Cu-chitosan nanoparticles, the chitosan-saponin nanoparticles were found poor in antifungal activity[25].

Nanoformulations are viewed to be safer and environment friendly option for plant disease management, but high toxicity of nanoparticles inadvertently released in the environment may pose greater threat to man and other organisms[26]. The ecotoxicological effects of nanomaterials on plant, and soil microorganisms have been widely explored[27]. There are many gaps in our knowledge on the agric-ecotoxicity of NPs and there are many unresolved problems and new challenges concerning the biological effects of these NPs[28]. There is a need for phytoxicity study on seed systems exposed to different concentration of nanoparticles dispersion to check phytotoxicity end point such as root length, percentage of germination, adsorption and aggregation of nanoparticles [29]. When nanosized silica-silver particles were applied under field condition to control of cucurbit powdery mildew, 100% control was achieve after 25 days[30]. These nanoparticles were found to be phytotoxic only at a very high dose of 3200 ppm when tested in cucumber and pansy plants. In order to understand the possible benefits of applying nanotechnology to agriculture, the first step should be to analyze penetration and transport of nanoparticles in plants. Since nanomaterial are introduced into the soil as a result of pepole behaviors, among the many field applications of nanotechnology, nanoparticles can enter soil through atmospheric routes and biosolids-amended agricultural soils[31-32]. Nanopesticides represent the next-generation to tradtional pesticides, as well as offer extra benefits such as high efficacy, durability, and less doses of active ingredients[33]. Nanofungicides can be prepared in a simple cost-effective manner are suitable for formulating new types of biohybrids nanocide materials would be use as a new environment friendly antimicrobial against different fungal pathogenic organisms of plant.

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