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Mini Review

Combating Bacterial Infection of Rice Using Magnetic Nanoparticles

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Abstract

Magnetic nanoparticles like Iron Oxide Nanoparticles (IONPs) hold the fundamental class in nanotechnology owing to their novel properties such as magnetism, biocompatibility, easy surface modification and encapsulation, uptake efficiency and release. Their interdisciplinary nature can be judged from the fact that it has also been applied in agriculture with the main purpose to increase productivity and improve nutrient use. Novel Fe_2O_3 nanoparticles are biocompatible and when efficiently surface coated showed enhanced antimicrobial activity against gram positive as well as gram negative bacteria. This review focuses on the potentials of IONPs as a competitive substitute of pesticides with high antimicrobial activity against a wide range of plant pathogens along with low negative impacts on the environment. Iron oxide nano formulations along with pesticides will be effective against the bacterial as well as fungal diseases of the rice plant.

Keywords: Nanoparticles; SPIONs; Biotherapeutics; Pesticides; Cytotoxicity

Introduction

A long before, agriculture antecedes industrial as well as technological revolution. The goal of agriculture is not only to cultivate soil and produce quality food grains but is a series gate innovation process involving opportunity identification, conceptual design and execution of opportunities. For example, opportunity identification in this regard are pervasive use of synthetic agro chemicals, manifested contamination and increased resistance of pathogenic microorganism posing as a serious concern for environment. Out of such an enquiry, an effort to develop bio-based and non-synthetic based alternatives of fertilizers and agro-chemicals have been aimed [1].

World population is reported to reach 10 billion by 2050. To meet the need of such a population, the major challenge is the management of agricultural practices which pushes sustainability of the system. Nanotechnology, is currently a promising breakthrough for improving our currently abysmal nutrient use efficiently. Nano-formulations of fertilizers and agro chemicals break the nutrient quality and yield barrier. These nano-carriers or particles are active, have increased solubilization and are target specific in action [2-4]. All these lead to an increased effectiveness, waste reduction, low dosage use and minimum adverse effect on environment as well as non-targeted organism. In addition, they also possess cheap industrial scalable synthesis.

Rice (*Oryza Sativa*) is an important cereal crop grown in different countries of the world. In India alone 44-62 million hectares yield 102.3 metric tons of rice. However, it is reported that, a wide gap exist between projected demand of rice and current level of production because of the various diseases of pathogenic origin. Current scenario elucidates the fact that the strategies and agro techniques for seed grain as well as hybrid rice production are expensive and require integrated management for success. Hence, questions arise in mind such as how can we stop rice crop destruction by pests or diseases, hence feeding such a huge population? How can nanotechnology play its role for minimizing destruction and maximizing yield of the crop?

Background Study

Million metric tons of food grains are wasted despite having green revolution. Various diseases in rice caused by bacteria are major bottleneck for a sustainable productivity. Various research groups are working extensively on the management of this kind of diseases like bacterial leaf blight. Out of different diseases which attack the crop, around 11 diseases are reported to be bacterial origin and are grouped into different types such as seedling, foliar, leaf sheath and grain and culm and root disease.

In light of this context, bacterial blight and bacterial leaf streak are said to have reduced Asia's annual rice production as much as 60% alone. The bacterial leaf blight exhibits symptoms like basal chlorosis and withering of the leaves. However, infected seedlings become reddish brown and desiccated. With severe infection, photosynthetic area reduces leading to the reduction in grain weight and retarded root growth. The disease is caused by *Pseudomonas plantarii*. It is a Gram-negative, non-spore forming, non-encapsulated rod with one to three polar flagella [5]. *P. plantarii* generates a compound known as tropolone, responsible for the retardation of root growth and leaf chlorosis of rice seedlings [5]. Similarly, *Xanthomonas Oryzae* causes bacterial blight and leaf steak disease and wreck the yields. Currently, seed treatment with bleaching powder (1000μg/mL) and zinc sulphate (2%) along with copper compounds are used for the disease management. It is reported that stable aqueous suspension and nanocomposites of Fe_3O_4 Ag showed significant antimicrobial activity against both type of bacteria [6]. It is reported that, iron compounds are capable of suppressing seedling blight, since the production of tropolone is inhibited in the presence of iron.

Nanotechnology sets promising avenue ensuring minimum damage to crops due to any kind of pest and disease as well as strengthen general crop performance. Metal NPs are chosen because they are essential metals for plants. This group includes metals based on Zn, Cu, Fe, Mn and their oxides. Zinc oxide and copper oxide NPs have been used in lot of commercial application such as pesticide formulation, agro fertilizers and plant nutrient formulas [7]. Zinc oxide has been used as anti-microbial agent as well as with supplementation by synthesizing them with soil fungi which showed positive results against pathogens as well as evidently increased uptake in crop and seed. It is thus currently employed in improving efficiency of Zn fertilizers. Similarly, magnetically controllable silver NPs with multifunctional phosphatriazine-based polymer showed promising results with nine bacterial strains and four candida species acting as antibacterial agents. However, there are a few potential risks and threats, removal of colloidal silver is difficult. In addition in zebra-fish model silver gave rise to health and ecotoxicity issues in concentration dependent manner [1].

However, Iron oxide NPs sets an ambitious goal. Throughout literature there is consistent evidence that INOP based fertilizers have increased the root length growth, plant height, biomass by regulating phytohormone content and antioxidant enzymatic activity in comparison to chelated Fe-fertilizers. Hematite and Maghemite being transition metal oxide nano particles shows cytotoxic as well as magnetic properties. Maghemite possesses insignificant in vitro cytotoxic propensity. However on coating or surface modification there is an evident increase in cytotoxicity. The amount of ROS generated at the bio-nano interface deforms the bacterial membranes, resulting in bacterial membrane damage. The ROS formed have the potential to make the viable bacterial cells into non-viable cells. It has also been noted that surface modification or coating of magnetic nanoparticles enhances the antimicrobial activity of nanoparticles [6-8]. Considering interaction at the Bio-Nano interface, IONP having positive surface potential will have stronger interactions at Bio-Nano interface in comparison to negative-IONP. Stronger the interaction, higher antimicrobial propensity [6].

On the basis of the above-mentioned research, magnetic nanoparticles, preferably ferromagnetic maghemite, might be effective against bacterial pathogens of rice. Superparamagnetic Iron Oxide Nanoparticles (SPIONs) are suitable candidates owing to their superior biocompatibility and superparamagnetic properties enabling prolonged accumulation and retention at target site with the help of external magnet [8] The biotherapeutics such as miRNS/siRNA, antibacterial peptides can be coated over SPION or even pesticides can be localized at the target diseased site of the plant imparting high therapeutic efficiency [9]. An external magnetic field can also accelerate cellular uptake of nanoparticles in 2D and 3D culture systems *in vitro*. The surface-modification of the SPION can also be done with hydrophilic or hydrophobic moieties and can be incorporated into micro/nanospheres via single/double emulsion method. Pesticides can be embedded within micro/nanospheres during formulations [8].

Conclusion

IONPs have attracted a great deal because of their proper surface architecture and targeting ligands/proteins making them biocompatible for various approaches. Bifunctional Fe_3O_4-Ag nanoparticles and the nanocomposites with antibacterial properties showed antibacterial activities against *E. coli, S. epidermidis* and *B. subtilis* etc. This review concludes that INOPs owing to their moderable surface potentials and accessible functional groups can be an effective way to culminate the diseases hampering rice production, hence maximizing the yield. Comparative studies have been done to explore the interaction pattern of IONPs with bacteria for evaluation of their antimicrobial propensities. Subsequently, nanoparticles have shown significant reduction in microbial infections and improved fertilizers and pesticides uptake efficacies of plants. Therefore, employing IONPs will also ensure drug delivery at specific targets, and at the same time the quantity of pesticides needed will be extremely less, hence it will be a very economic approach as well.

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