NANOTECHNOLOGY IN PLANT GROWTH PROMOTION AND PROTECTION

RECENT ADVANCES AND IMPACTS

EDITED BY **AVINASH P. INGLE**

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Nanotechnology in Plant Growth Promotion and Protection

Recent Advances and Impacts

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Preface

Agriculture is the backbone of several developing countries because their economy is directly relying on agriculture; moreover, developed countries are also depending on agriculture for their food. However, a continuous increase in the worldwide population and currently available agricultural practices has led to major global concerns such as production and supply of good quality food, and food security. To date, various advancements have been made in agriculture through the discovery of effective agrochemicals and other farming technologies. Despite all these developments, agriculture is still facing several severe challenges like crop loss due to plant pathogens, soil fertility issues due to extensive use of synthetic agrochemicals, soil pollution, imbalance of beneficial microflora, resistance in microbial pathogens, etc. Unfortunately, the extensive use of synthetic agrochemicals like pesticides, fungicides, and fertilizers, are mostly responsible for all these problems. Therefore, it is need of the hour to develop effective farming technologies in addition to the development of potent, economically viable, and eco-friendly products that can sustainably manage the plant pathogens and enhances crop production.

In this context, nanotechnology can be used as the most innovative solution for such issues and has the great potential to rapidly take forward the agriculture and allied sectors with the help of modern tools. The nanomaterials can be effectively used in the development of various nano-based products like nanoantimicrobials and nanofertilizers. Moreover, various nanoparticles can also be used as nanoscale carriers for the delivery of agrochemicals and other nutrition. Besides, modern nano-based tools can be

promisingly used in precision farming for the detection of plant pathogens, nutrient deficiencies, etc. The use of above-mentioned nano-based products helps to enhance plant growth, protect plants through the management of plant pathogens, and also reduces soil pollution. Considering these facts, the editor attempted to discuss the recent advances and role of nanotechnology in plant growth promotion and protection through this book.

In this book there are total 15 chapters, which are broadly focused on the recent advances and the role of nanotechnology in plant growth promotion and protection. Chapter 1 is mainly focused on effective application of nanotechnology in agriculture, particularly, in plant growth promotion and control of plant diseases through the management of plant pathogens. Chapter 2 is about the application of titanium-based nanomaterials such as titanium dioxide nanoparticles in plant growth. In this chapter, various aspects like the interaction of nanoparticles with plants and their pathways and the effects of different concentrations of titanium dioxide nanoparticles on plant growth have been discussed. In Chapter 3, authors reviewed the role of different zinc-based nanoparticles in plant growth promotion and protection. The focus has been given on the effects of nanoparticles when used through different modes of application like foliar application, soil, and hydroponic application. Chapter 4 specifically focused on the application of nanomaterials in the form of nanofertilizers as an effective alternative to chemical fertilizers. Further, uptake, translocation, and fate of nanofertilizers in plants have been also elaborated. Chapter 5 discusses the role of nanobiotechnology in sustainable agriculture through the applications of various nanomaterials in plant nutrition and protection. In Chapter 6, the authors discussed how nanotechnology can be useful in enhancing the immunity of plants through its application

in seed and soil. Chapter 7 is focused on the effects of natural organic matter on the bioavailability of elements from inorganic nanomaterials. Particularly, the emphasis has been given on the effects of organic matter on different properties of nanoparticles such as aggregation and agglomeration, dissolution, and bioavailability. Chapter 8 emphasizes on different biotic and abiotic stresses in plants and the induction of tolerance against such stresses in crops after application of nanomaterials. In Chapter 9, the authors reviewed the role of different nanoparticles as elicitors of biologically active ingredients in plants. Moreover, various other aspects like routes of exposure, uptake, and interaction of nanoparticles into plant cells, elicitation of different bioactive molecules like polyphenols, alkaloids, and terpenoids, essential oils have been thoroughly explained. Chapter 10 is dedicated to the use of various nanoparticles in plant growth promotion and the management of a variety of plant pathogens. Besides, the influence of nanoparticles on plant photosynthesis, enhancement of root and shoot growth, phytopathogen suppression, etc. has been briefly discussed. Chapter 11 focused on the application of metal-based nanoparticles in plant protection. In this chapter, the authors discussed role of different metal-based nanoparticles like silver, copper, zinc, titanium, and magnesium in plant protection. Apart from this, various possible antimicrobial mechanisms for metal-based nanoparticles have been also briefly elaborated. Chapter 12 is dedicated on the role of zinc-based nanoparticles in the management of plant diseases. Chapter 13 emphasizes on effects of different metal oxide nanoparticles on plant growth. In this chapter, authors presented the positive and negative effects of different metal oxide nanoparticles in a variety of plants. Chapter 14 is focused on the most important and relevant aspects, i.e. biostimulation and toxicity of nanomaterials in plants. This chapter explained how nanoparticles can stimulate the

biological response and toxicity in plants. However, final Chapter 15 is completely dedicated to toxicological concerns of nanomaterials in agriculture. Moreover, special emphasis has been given on various important aspects like uptake and translocation of nanomaterials in plants, various factors affecting the uptake and translocation of nanomaterials, etc. In addition, how nanomaterials affect the defense mechanisms of plants and generate phytotoxicity has been also discussed.

Overall, this book covers very informative chapters written by one or more specialists, experts in the concerned topic. Hence, I would like to offer a very rich guide for researchers in this field, undergraduate or graduate students of various disciplines like agriculture, biotechnology, and nanotechnology and allied subjects. In addition, this book is useful for people working in various agriculture and food-based industries, regulatory bodies, and agriculture-related organizations.

I would like to thank all the authors for their outstanding efforts to provide state-of-the-art information on the subject matter of their respective chapters. Their efforts will definitely enhance and update the knowledge of the readers about the role of nanotechnology in agriculture particularly, in plant growth promotion and protection. I also thank everyone in the Wiley team for their constant help and constructive suggestions particularly to Rebecca (Senior Editor), Kerry, Nivetha and other team members. I am highly thankful to Science and Engineering Research Board (SERB), Department of Science and Technology, Government of India, New Delhi for providing financial assistance in the form of “Ramanujan Fellowship”.

I hope that the book will be useful for all the readers to find the relevant information on the latest research and advances in effective use of nanotechnology in agriculture.

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Nanotechnology as a Smart Way to Promote the Growth of Plants and Control Plant Diseases: Prospects and Impacts

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1.1 Introduction

Nanotechnology is a modern and creative science which involves the designing, manipulation, and use of nanoscale materials (Ali et al. 2014; Agrahari and Dubey 2020). The term “nano” is a Greek word which actually means “dwarf,” and when it is used to describe materials, it is supposed to have at least one dimension of 100 nm or less. Today, nanotechnology has entered in every aspect of day to day life (Zulfiqar et al. 2019). In medicine, nanotechnology has made breakthrough improvements as a means of smart drug delivery systems and many other applications. When it comes to agriculture field, research is still under way to discover the applications of nanomaterials to improve plant growth and control plant diseases (Ali et al. 2014; Zulfiqar et al. 2019; Agrahari and Dubey 2020).

Nanomaterials or nanoparticles can be manufactured using different ways, such as top-down and bottom-up approach. The production of nanomaterials through top-down approach involves the breaking down of bulk materials into nanosized structures or particles. The disadvantage of this