

# Preface

Nanotechnology and nanomaterials are increasingly imparting its great influence in our life and environment. During the last two decades, significant amount of research has been conducted in nanotechnology focusing on their application in electronics, energy, mechanics, and life sciences including plant sciences. The impact of nanotechnology and nanomaterials is inevitable in the field of agriculture, and many researches are evidencing their potential in improving the food and agricultural systems through different approaches resulting in the enhancement of agricultural output and development of new food and food products, etc.

The early research investigations in this direction documented absorption, translocation, accumulation, and effects of nanomaterials, mostly metal-based and carbon-based, in several plants including crops. Many of these research studies evidenced for the potential utility of nanomaterials in crop improvement as demonstrated by enhanced germination and seedling parameters in rice, maize, wheat, alfalfa, soybean, rape, tomato, radish, lettuce, spinach, onion, pumpkin, and cucumber; and also enhanced nitrogen metabolism, chlorophyll content, and activities of several enzymes leading to enhanced photosynthesis in maize, soybean, peanut, tomato, and spinach.

There are many investigations reported on nanomaterial-induced improvement in agronomic traits including yield, biomass content, and content of secondary metabolites by direct treatment in soybean, bitter melon, and rice indicating the ability of the nanomaterials in modifying genetic constitution of plants. Nanomaterials have exhibited promise in targeted gene delivery for developing atomically modified plants—a safer and acceptable strategy in contrast to genetic engineering. Interestingly, generational transmission of nanomaterials has been documented in rice and bitter melon.

The usage of these nanomaterials can ultimately land in our food cycle and so a careful study and analysis is pertinent regarding their usage before putting these materials in actual use.

The spurt in the research in this interdisciplinary field that involves primarily the fusion of nanotechnology and plant science may lead to the creation of a new field as “Plantnanomics.”

Nanomaterials have also exhibited promise for precise and environmentally safe application of fertilizers and plant protection chemicals using nanoformulations besides plant disease management using nanosensors and nano-based diagnostic kits.

Some concerns have been raised about potential adverse effects of nanomaterials on biological systems and environment although carbon-based nanomaterials, in general, have been found to be safe in many instances.

The book “Plant Nanotechnology” comprises 15 chapters. Chapter 1 clearly lays out the foundation of the book by providing the overview of the concepts, strategies, techniques, and tools of nanobiotechnology and its promises and future prospects. Before using the nanomaterials, we should know its physical and chemical properties. Based on the properties, we can decide the use of the materials in different applications. Chapter 2 deals with the physical and chemical nature of the nanoparticles. After characterizing the nanomaterials, we can employ them in intended applications in plants. While doing that we should know how it could be applied and how we could detect and quantify the uptake of the nanomaterials, translocation, and accumulation. Chapter 3 is devoted to provide the information about the quantification of uptake, translocation, and accumulation of nanomaterials in plants.

For application of any materials anywhere, we should have a clear-cut know-how, such as how it can be applied and what are the different ways. Chapter 4 describes various methods for using nanomaterials. After the usage of the nanomaterials, naturally we have to look for their impact on plants. The earlier indication of their impact can be assessed by the germination, seedling parameters, and physiological attributes. Chapter 5 deals with the assessment of the impact of nanomaterials on plant growth and development. Chapter 6 provides the information on the effects of nanomaterials on plants with regard to physiological attributes.

After laying a very good foundation toward the characterization and application of nanomaterials and their impact, in general, in plants, we are discussing on the response of plants to nanoparticles at molecular level including changes in gene expression (Chap. 7), and movement and fate of nanoparticles in plants and their generational transmission (Chap. 8).

Recent researches have shown that nanomaterials can be used for the improvement of yield of crops and quality. This finding will lead to the application of nanomaterials in agriculture. For shedding light on the use of nanomaterials in agriculture for different applications, Chap. 9 has been incorporated to elucidate the potential of nanomaterials for the enhancement of yield, plant biomass, and secondary metabolites. A highly promising application potential of nanomaterials for delivery of genetic materials has been deliberated in Chap. 10. Application of agrochemicals including fertilizer and plant protection chemicals using conventional methods leads to less effectivity and even pollution of plant products, soil,

water, and air. In contract, use of nanomaterials can lead to precise and targeted delivery of these chemicals. Utilization of nanoparticles for delivery of fertilizers and for plant protection has been deliberated in Chap. 11 and Chap. 12, respectively. We have included another chapter (Chap. 13) to discuss the impact of the nanomaterials in soil-plant systems.

Use of nanomaterials can arouse the concern of safety of their usage with regard to human health and environment. This concern led us to include the Chap. 14 that deals with the concerns of hazards of nanomaterials to human health and environment and also critical views on compliances.

As mentioned earlier, nanotechnology and nanomaterials are increasingly finding their application in the field of agriculture; time has come for the policy makers and researchers to think and depict a road map for the use of nanotechnology in future. Chapter 15 has been specially designed for enumerating on the future road map for plant nanotechnology.

The fifteen chapters of this book have been authored mostly by different teams of scientists dealing with various aspects related to the concepts, strategies, techniques, and tools of plant nanotechnology focusing on the application potential and also on concern for nanotoxicity. Hence, some overlapping contents, particularly on a few fundamental aspects of nanomaterials including their types, natures, and impacts, are obvious. However, the responsibility lies on us as the editors for such redundancy and for addressing them in the future editions of this book.

We believe that our book “Plant Nanotechnology” provides a very precise discussion pertinent to the application of nanotechnology and nanomaterials in plant sciences so that by reading the book, any student, researcher, or policy maker can appreciate the potential and the tremendous application value of this approach and can have a precise and clear idea as to what is going on in this field.

We express our sincere thanks to the 23 scientists beside us for their chapters contributed to this book and their constant cooperation from submission of the first drafts to revision and final fine-tuning of their chapters commensurate with the reviews.

Finally, we wish to extend our thanks to Springer Nature and its entire staff particularly Dr. Christina Eckey and Dr. Jutta Lindenborn involved in publication and promotion of this book that will hopefully be useful to students, scientists, industries, and policy makers.

Mohanpur, India  
Kawagoe, Japan  
Little Rock, USA

Chittaranjan Kole  
D. Sakthi Kumar  
Mariya V. Khodakovskaya

Plant Nanotechnology

Principles and Practices

Kole, C.; Kumar, D.S.; Khodakovskaya, M.V. (Eds.)

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