Smart Nanomaterials Technology

Sezai Ercişli · S. Rakesh ·
Rahul Datta · Deepranjan Sarkar ·
Sachidanand Singh *Editors*

Nanotechnology Applications in Soil Science

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Editors
Sezai Ercişli
Department of Horticulture
Faculty of Agriculture, Atatürk University
Erzurum, Türkiye

Rahul Datta
Department of Geology and Pedology
Mendel University in Brno
Brno, Czech Republic

Sachidanand Singh
Department of Biotechnology
School of Energy Technology
Pandit Deendayal Energy University
Gandhinagar, Gujarat, India

S. Rakesh
Department of Resilient Farming Systems
International Crops Research Institute for the Semi-Arid Tropics
Hyderabad, Telangana, India

Deepranjan Sarkar
Agricultural Systems and Engineering
Faculty of Food, Agriculture and Natural Resources
Asian Institute of Technology
Khlong Luang, Pathum Thani, Thailand

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Preface

Soil security is crucial for harnessing soil ecosystem services and maintaining agricultural productivity, biodiversity conservation, and environmental health. Global soil deterioration due to mismanagement is a critical issue that threatens food security and ecosystem health. Nanotechnology represents an emerging revolution with extensive applications in the field of soil science. It employs a smart delivery system that enhances nutrient use efficiency and crop growth and minimizes nutrient losses and environmental impact. Our book emphasizes how we can leverage the benefits of nanotechnology to enhance soil health, improve plant nutrition, and ensure environmental safety, thereby advancing the understanding and practice of soil science.

Recent advancements in the synthesis, characterization, and use of nanomaterials in agriculture have revolutionized farming practices, enabling more efficient nutrient delivery and enhanced crop resilience against environmental stresses. The synthesis of nanomaterials, particularly through eco-friendly approaches, offers innovative solutions to persistent agro-environmental challenges. In addition to soil fertility management, nano-enabled products are utilized for enhancing plant growth, development, and protection; they also play a significant role in climate mitigation. The effects of nanomaterials on soil properties (physical, chemical, and biological) have been discussed in the book. Soil amendments such as nanobiochar further contribute to improved soil health and climate change mitigation. One of the chapters delves into the complexities of metal-based nanoparticles and their interactions with soil microbes. Another chapter highlights the use of nano-sensors to monitor heavy metal contamination in soils and plants. Studying the fate and transport of nanoparticles in soil systems is crucial for understanding their environmental impact and potential risks, including those to human health. Nanotechnology offers promising solutions for eliminating contaminants in soil and water, utilizing engineered nanomaterials. Nanomaterials have emerged as a suitable strategy for addressing environmental pollution and promoting sustainable agriculture, offering transformative solutions across various domains.

The chapters have been compiled with outstanding contributions from a diverse range of authors. We are thankful to all the contributors and mentors associated with the project. We hope this book serves as a valuable resource for enhancing the understanding of students, scientists, program coordinators, decision-makers, and anyone interested in the subject. Additionally, it provides a forum for plant and soil scientists to address the challenges of soil management and food production.

Erzurum, Türkiye — Sezai Ercişli
Hyderabad, India — S. Rakesh
Brno, Czech Republic — Rahul Datta
Khlong Luang, Thailand — Deepranjan Sarkar
Gandhinagar, India — Sachidanand Singh

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Nanotechnology for Soil Health: Applications, Improvements, and Environmental Benefits

P. Smriti Rao, Faria Fatima, Abdul Mazeed, Saba Siddiqui, and Mohammed Haris Siddiqui

Abstract Agriculture provides sustenance and raw materials to the building, energy, fabric, and pharmacological industries. Agrochemical overuse, soil degradation, urbanization, unsustainable resource use, biodiversity loss, air pollution, and climate change are just a few of the worrisome problems facing agriculture today that demand prompt attention. These problems are too complex, labor-intensive, time-consuming, inefficient, demand a lot of crop nutrients, and are not suited for conventional agricultural methods to handle. Furthermore, the excessive use of agrochemicals poses a serious threat to ecological integrity. As a result, researchers, farmers, and decision-makers are never done looking for innovative ways to address pressing issues. Growing evidence points to nanotechnology as the new sustainable agricultural savior. Nanosensors have been used in agri-fields not only for precision farming but also for the recognition of chemically hazardous analytes and crop diseases. Additionally, there are many amazing uses of nanotools in agriculture, including sensing, photocatalysis, and the delivery of agrochemicals. This chapter covers in detail the many amazing ways that nanotechnology has been used to overcome the shortcomings of traditional agronomic approaches as well as the potential applications that nanotechnology may have in the future.

Keywords Nanoparticles · Nanofertilizers · Nanosensors · Soil characteristics · Greenhouse gas emissions

1 Introduction

The United Nations is committed to achieving the pioneering target of ending poverty and deprivation and certifying the sustainability of agriculture in accordance with the Sustainable Development Agenda of 2030. There will be 9.8 billion people on the earth by 2050, with the majority living in developing nations. This means that

P. Smriti Rao (✉) · F. Fatima · A. Mazeed · S. Siddiqui · M. H. Siddiqui
Department of Agriculture, Integral Institute of Agricultural Science and Technology, Integral University, Lucknow, India
e-mail: smritirao19@gmail.com

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