Plant Nanotechnology

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Editors

Plant Nanotechnology

Principles and Practices

Springer

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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 knowhow, 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.

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Contents

Abbreviations

μ-XANES	Micro-X-ray absorption spectroscopic near-edge structure
μ-XRF	Micro-X-ray fluorescence
2,4-D	2,4-Dichlorophenoxyacetic acid
2-DE	Two-dimensional electrophoresis
3D	Three-dimensional
ADS	Amorpha diene synthase
AES	Atomic absorption spectrometry
AF4	Asymmetrical flow-field flow fractionation
AFM	Atomic force microscopy
AgNP	Silver nanoparticle
Al_2O_3	Aluminum oxide
ALDH	Aldehyde dehydrogenase
APX	Ascorbate peroxidase
ARGOS	Auxin-regulated gene involved in organ size
AuCapped-MSN	Mesoporous silica nanoparticle closed end with gold nanoparticle
AuNP	Gold nanoparticle
AuNR/Ag	Plasmonically active nanorods based on gold cores and silver shells
BET	Brunauer–Emmett–Teller
BP	Bulk particle
BSE	Backscattered electron
BY-2	Tobacco bright yellow-2 cell line
CAT	Catalase
CB	Carbon based
CB NP	Carbon-based nanoparticle
CEC	Cation exchange capacity
CeO_2	Cerium dioxide
CeO_2 NPs	Cerium oxide nanoparticles
Cfu	Colony-forming unit

CLSM	Confocal laser scanning microscopy
CM	Confocal microscopy
CNM	Carbon-based nanomaterial
CNT	Carbon nanotube
CPN	Conjugated polymer nanoparticle
CPS	Counts per second
CSCNT	Cup-stacked carbon nanotube
CS-Se NP	Chitosan-modified selenium nanoparticle
DBR2	Double-bond reductase
DDE	Dichlorodiphenyldichloroethylene
DF-STEM	Dark-field scanning electron microscopy in transmission mode
DLS	Dynamic light scattering
Ebeam	Electron beam
EDAX	Energy dispersive analysis of X-rays
EDX	Energy dispersive X-ray spectrometer
EELS	Energy loss spectroscopy
EM	Electron microscopy
ENM	Engineered nanomaterial
ENP	Engineered nanoparticle
EPA	European Parliament
ER	Endoplasmic reticulum
EXAFS	Extended X-ray absorption fine structure
Fe_3O_4	Magnetite
FEG	Field emission gun
FFF-ICP-MS	Field flow fractionation inductively coupled plasma mass spectrometry
FIFRA	Federal Insecticide, Fungicide and Rodenticide Act
FITC	Fluorescein isothiocyanate
FS	Fullerene soot
FTIR	Fourier-transformed infrared
GA	Gum arabic
GC	Gas chromatography
GLP	Germin-like protein
GMO	Genetically modified organism
GO	Graphene oxide
GPS	Global positioning satellite
GSH	Glutathione
HA	Humic acid
HAP	Hydroxylapatite
HPLC	High-performance liquid chromatography
HRTEM	High-resolution transmission electron microscopy
HS-AFM	High-speed atomic force microscopy
ICDD	International Center for diffraction Data
ICP	Inductively coupled plasma
ICP-MS	Inductively coupled plasma mass spectrometry

ICTA	International Center for Technology Assessment
IDMS	Isotope dilution mass spectrometry
IgG	Immunoglobulin G
In_2O_3	Indium oxide
JCPDS	Joint Committee on Powder Diffraction Standards
LaB6	Lanthanum hexaboride
LA-ICP-MS	Laser ablation inductively coupled plasma mass spectrometry
LC-ESI-MS/MS	Liquid chromatography electrospray ionization tandem mass spectrometry
LM	Light microscopy
MB NP	Metal-based nanoparticle
MeJA	Methyl jasmonate
miRNA	Micro-RNA
MNM	Manufactured nanomaterial
MS	Mass spectrometry
MSN	Mesoporous silica nanoparticle
MSNS	Mesoporous silica nanoparticle system
MWCNT	Multi-walled carbon nanotube
$NaBH_4$	Sodium borohydrate
nAg	Silver nanoparticle
Nano Fe_2O_3	Nano ferric oxide
$nCeO_2$	Cerium dioxide nanoparticle
NDEA	N-nitroso-diethylamine
NGS	Next-generation sequencing
NM	Nanomaterial
NOM	Natural organic matter
NOx	Nitric oxides
NP	Nanoparticle
NR	Nanorod
NS	Nanosphere
NSS	Nanosized Ag–silica hybrid
NT	Nanotechnology
$nTiO_2$	Titanium dioxide nanoparticle
OES	Optical emission spectrometry
OPO	Optical parametric oscillator
PCD	Programmed cell death
PHSN	Porous hollow silica nanoparticle
PIP	Plasma membrane intrinsic protein
PIXE	Particle-induced X-ray emission
PLA	poly(L-lactide)
POX	Peroxidase
PR	Pathogenesis-related
PVP	Polyvinylpyrrolidone

QD	Quantum dot
qRT-PCR	Quantitative real-time polymerase chain reaction
RAPD	Random amplified polymorphic DNA
RER	Rare earth element
ROS	Reactive oxygen species
SA	Salicylic acid
SADS	Selected area (electron) diffraction
SAR	Systemic acquired resistance
SE	Secondary electrons
SEM	Scanning electron microscope
SERS	Surface-enhanced Raman spectroscopy
SiO2	Silicon dioxide
SIP	Small and basic intrinsic protein
SNP	Silver nanoparticle
SOD	Superoxide dismutase
SP-ICP-MS	Single particle inductively coupled plasma mass spectrometry
SPION	Super paramagnetic iron oxide nanoparticle
SPR	Surface plasmon resonance
SQS	Squalene synthase
SR	Synchrotron radiation
Sr31	Wheat stem rust gene
STEM	Scanning electron microscopy in transmission mode
SWCNH	Single-walled carbon nanohorn
SWCNT	Single-walled carbon nanotube
TEM	Transmission electron microscopy
TiO_2	Titanium dioxide
TIP	Tonoplast intrinsic protein
TMA-OH	Tetramethyl ammonium hydroxide
TMAPS/F-MSNs	N-trimethoxysilylpropyl-N,N,Ntrimethylammonium chloride-labeled MSNs
TNB	Temple northeastern Birmingham
TPEM	Two-photon excitation microscopy
TSC	Trisodium citrate
TUNEL	Terminal deoxynucleotidyl transferase-mediated dUTP nick end-labeling
TXM	Transmission X-ray microscopy
Ug99	Uganda99 (race)
USEPA	United States Environmental Protection Agency
USDA	United States Department of Agriculture
XANES	X-ray absorption near-edge structure
XAS	Synchrotron X-ray absorption spectroscopy
XRD	X-ray diffraction

ZnO	Zinc oxide
ZnO NP	Zinc oxide nanoparticle
$ZnTiO_3$	Zinc titanate