

Frontiers in Biological Sciences: Recent Advances and Innovations-Vol I

Editors

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PREFACE

This book presents a collection of research articles spanning diverse areas within the life and environmental sciences. Several studies focus on cancer, exploring the role of heat shock protein 90 in cell death pathways and investigating the therapeutic potential of *Withania somnifera* and other natural inhibitors. The book also covers advancements in green nanotechnology, detailing the synthesis and antimicrobial applications of silver nanoparticles, with a specific examination of green tea catechins. Sustainable practices are addressed through research on biofuel production from agricultural waste and the use of edible coatings for preserving fruits and vegetables. Plant biology is represented by studies on the role of phytohormones in secondary metabolite synthesis and the effects of drought stress. Finally, the book introduces virus-induced gene silencing (VIGS) as a valuable tool for plant genetic research. The collection highlights current research trends and potential applications in medicine, environmental science, agriculture, and biotechnology. This compilation aims to serve as a valuable resource for researchers, educators, and students, offering insights that are both profound and practical.

We extend our sincere gratitude to all the authors who have contributed their expertise and insights to this volume. Their dedication and passion for advancing the frontiers of biological science have made this publication possible. The book will not only enhance the scientific community's knowledge base but also inspire future generations of biologists to push the boundaries.

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Chapter - 11

Impact of Heavy Metals on Plant Health: Exploring Toxicity and Oxidative Stress

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ABSTRACT

Heavy metals, naturally occurring elements with high atomic weight and density, pose significant threats to plant health when present in elevated concentrations. This chapter provides the information on the intricate relationship between heavy metals and plants, highlighting the dual challenges of toxicity and oxidative stress. Plants are routinely exposed to heavy metals such as cadmium (Cd), lead (Pb), Copper (Cu), mercury (Hg), arsenic (As), and chromium (Cr) through contaminated soil and water sources. These metals, when absorbed by plant roots, can translocate to aerial parts, disrupting physiological and biochemical processes. Heavy metal toxicity manifests in plants through a variety of detrimental effects, including inhibition of photosynthesis, impaired nutrient uptake, and disruption of cellular structures. A primary consequence of heavy metal exposure is the induction of oxidative stress, a state characterized by the overproduction of reactive oxygen species (ROS) such as superoxide radicals, hydrogen peroxide, and hydroxyl radicals. While ROS are naturally generated in plants during metabolic processes, their levels are tightly regulated by antioxidant defense mechanisms. However, heavy metals disrupt this balance, leading to an excessive accumulation of ROS. This oxidative burst can damage cellular components, including lipids,

proteins, and DNA, thereby exacerbating the toxic effects of heavy metals. Plants have evolved complex defense strategies to mitigate heavy metal-induced oxidative stress. These include the synthesis of metal-binding proteins like phytochelatins and metallothioneins, the activation of antioxidant enzymes such as superoxide dismutase, catalase, and peroxidases, and the upregulation of non-enzymatic antioxidants like ascorbate and glutathione. Despite these adaptive responses, the efficiency of these mechanisms varies among plant species and is often insufficient to fully counteract heavy metal toxicity under severe contamination.

Keywords: Heavy metals, oxidative stress, ROS, phytochelatins, superoxide dismutase, catalase.

Introduction

Heavy metals are heterogeneous group of elements varied in their functions and chemical properties. Heavy metals mainly belong to the transition element in the Periodic Table. Heavy metals are those elements which have specific weight of more than 5 g cm^3 . The metals that are at least 5 times denser than water are also defined as Heavy Metals. Heavy metals are either essential (Mo, Mn, Cu, Ni, Fe, Zn) or non-essential metals (Cd, Ni, As, Hg, Pb)¹. Essential metals maintain metabolism of human body like Cu is essential for hemoglobin formation, carbohydrate metabolism but if these are present in excess, it causes cellular damage². Likewise, many heavy metals are also essential for plants as they act as a cofactor, activate the enzyme reaction, and show ductility, conductivity and provide cation stability³. However, these metals present in more than the required concentration, they show toxicity. Deficiencies of essential heavy metals affect human health and agricultural productivities. Non-essential metals show toxic effect even at low concentrations. They neither metabolized in other intermediate compounds nor break down in the environment. Due to the industrial, domestic, agricultural, medicinal, technological application or events like