

Preface

The extensive increase of world population and industrial management has produced numerous environmental problems such as pollution (e.g. water, air, soil, noise and radiation), accumulation of heavy metals in soil and reduction in water quality. These facts can produce severe deterioration of natural resources, disturbance of ecosystems and affect human health. The term “heavy metal” refers to metallic elements with a high specific gravity (more than 5) or density which are very toxic even at very low concentrations. Some of these elements are referred as the trace elements, including iron (Fe), copper (Cu), manganese (Mn), molybdenum (Mo), cobalt (Co) and zinc (Zn), which are essential for biological systems in small quantities by participating in redox reactions and acting as enzyme cofactors (Sanità di Toppi and Gabbrielli 1999). However, these metals can be toxic at high concentrations. Other heavy metals, such as cadmium (Cd), mercury (Hg), lead (Pb), aluminum (Al) or arsenic (As), have no function as nutrients and are very toxic to plants, animals and humans. The toxicity of these metals is based on their chemical properties which allow them to promote the production of reactive oxygen species (ROS), inactivation of enzymes, basically by reaction with SH-groups, and displacement of other cations or metals from proteins (Sanità di Toppi and Gabbrielli 1999).

Heavy metals appear in the environment through natural sources or by anthropogenic activities such as mining, fossil fuel combustion, phosphate fertilizers used in agriculture and metal-working industries (Clemens 2006). These human activities have produced a severe environmental concern in some parts of the world because of the contamination by metals in day-to-day life, which can even compromise the health of future generations, due to the persistence of the metals in the environment by their bioaccumulation through the food chain (Clemens 2006). Tolerance to heavy metals in plants may be defined as the ability to survive in a soil that is toxic to other plants and is manifested by an interaction between the genotype and its environment (McNair et al. 2000). Some plants have developed resistance to high metal concentrations, basically by two mechanisms, avoidance and tolerance. The first mechanism involved exclusion of metals outside the roots, and the second mechanism consists basically in complexing the metals to avoid

protein and enzyme inactivation. Some plants can also accumulate metals in their tissues at concentrations higher than those found in the soil, and these plants are referred to as hyperaccumulators. Most hyperaccumulator plant species belongs to the Brassicaceae family. Heavy metal hyperaccumulation in plants is due to a combination of metal transporters and chelator molecules. Chelation of metals in cytosols by high affinity ligands is potentially a very important mechanism of heavy metal detoxification and tolerance. Potential ligands include amino acids, nicotianamine, phytochelatins and metallothioneins (Clemens 2001). Phytochelatins have been the most widely studied in plants with a general structure $(\gamma\text{-Glu Cys})_n\text{-Gly}$ where $n = 2\text{--}11$, and are rapidly induced in plants by heavy metal treatments (Rauser 1995). Hyperaccumulation can be exploited as a very useful tool to clean contaminated soils, water and sediments by the process called phytoremediation which essentially uses green plants to clean-up contaminants.

During the last two decades, ROS has gained importance in different aspects of heavy metal stress. Under physiological conditions, there is a balance between production and scavenging of ROS in all cell compartments. However, this balance could be perturbed by a number of adverse environmental factors. One of the major consequences of heavy metal action is enhanced production of ROS giving rise to damage to membranes, nucleic acids, and proteins (Halliwell and Gutteridge 2000). However, ROS are double-faced molecules acting as signal molecules regulating a large gene network in response against biotic and abiotic stress. On the other hand, nitric oxide (NO) also gained much importance in the last decade, as basically NO is a gaseous reactive molecule with a pivotal signaling role in many developmental and cell response processes (Besson-Bard et al. 2008). Recently, an increasing number of studies have been reported on the effects of NO alleviating toxicity of heavy metal including Cd and As (Xiong et al. 2010). Changes in the levels of both molecules are associated in the perception of stress and can trigger the defence cellular responses against adverse environmental conditions. In plants, hormones also play a critical role in the regulation of growth/development and modulation in plant responses against stresses. ROS and plant hormones interplay in the regulation of those processes, although the mechanisms involved are not well known in most cases.

The number of publications focused on heavy metal toxicity in plants has been growing exponentially in the last decade. The purpose of this book is to present the most recent advances in this field, mainly on the uptake and transport of heavy metals in plants, mechanisms of toxicity, perception of metals and the regulation of cell responses under metal stress. Another key feature of this book is related to the studies in recent years on signaling and remediation processes taking advantage of recent technological advances including “omic” approaches. Transcriptomic, proteomic and metabolomic studies have become very important tools to analyze the dynamics of changes in gene expression, and the profiles of protein and metabolites under heavy metal stress. This information is also very useful to draw the complex signaling and metabolic network induced by heavy metals in which hormones and reactive oxygen species also have an important role. Understanding the mechanism involved in sequestration and hyperaccumulation is very important

in order to develop new strategies of phytoremediation are reviewed in several chapters of this book. The information included in this book will bring very stimulating insights into the mechanism involved in the regulation of plant response to heavy metals, which in turn will contribute to improving our knowledge of cell regulation under metal stress and the use of plants for phytoremediation.

The editors are grateful to the authors for contributing their time, knowledge and enthusiasm to bring this book into being.

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