Chapter 1

Effect of Metals on Hydrophyte Growth and Development Toxicity and Tolerance Mechanisms

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ABSTRACT

Abstract Heavy metal pollution in aquatic ecosystems presents a severe environmental hazard, adversely impacting the growth, physiology, and survival of hydrophytes plants specialized for water-saturated habitats. This chapter examines the intricate interactions between heavy metals and hydrophyte systems, emphasizing the physiological, biochemical, and molecular mechanisms that govern metal toxicity and plant tolerance. This chapter provides a comprehensive overview of the effects of heavy metal toxicity on the growth, development, and physiological functions of hydrophytes, with a particular focus on their mechanisms of tolerance and detoxifi-

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cation. Heavy metals such as cadmium (Cd), lead (Pb), mercury (Hg), arsenic (As), chromium (Cr), and nickel (Ni) are known to disrupt vital metabolic and cellular processes in hydrophytic species.

INTRODUCTION

Contamination by heavy metals has become one of the most serious issues on the environmental front, posing much danger to both aquatic and terrestrial life. High rates of industrialization, mining, and urban sewage, and high-intensity agriculture activities have caused a steep rise in heavy metals, including cadmium (Cd), lead (Pb), mercury (Hg), arsenic (As), and chromium (Cr) concentrations in water (Ali et al., 2013; Nagajyoti et al., 2010). In contrast to organic pollutants, heavy metals are non-biodegradable, as they remain in the water bodies over a long period and are subjected to the processes of bioaccumulation and biomagnification via a food chain (Jaishankar et al., 2014). The high concentrations of these metals pose a significant toxicological danger to marine flora, fauna, and human beings; hence, their cleanup is an urgent environmental concern. The essentiality of plants in supporting the stability of aquatic ecosystems means that hydrophytes, or plants that are able to grow in part or entirely in water, assume a central position. Nevertheless, they are susceptible to their physiological and biochemical disturbances when subjected to high levels of heavy metals, which have an adverse effect on growth, reproduction, and survival (Mishra et al., 2006). Some of the symptoms of toxicosis in hydrophytes include growth retardation, chlorosis, necrosis, compromised photosynthesis, and inhibition of enzyme activities (Singh & Tewari, 2003).

The vulnerability of the hydrophytes to heavy metals is dependent on the type of metal, concentration, and duration of exposure factors with regard to species. Some species exhibit very strong tolerance mechanisms, even allowing them to withstand and flourish in metal-stressed conditions. These defense mechanisms incorporate entrapping metal by vacuoles, production of metal-bound peptides such as phytochelatins and metallothioneins, activation of antioxidants counteract and changes in morphology, including a change in root shape (Sharma & Dubey, 2005; Prasad, 2004). In light of these implications, there is a timely need to tap into the physiological adaptations of hydrophytes to improve the heavy metal remediation process without necessarily affecting the environmental characteristics (realistic, affordable, and viable) (Ali et al., 2013).

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