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REVIEW ARTICLE

Plant toxicity of four HMs: Arsenate, cadmium, chromium and lead: A mini review

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Abstract

The presence of heavy metals (HMs) in agricultural soils plays a crucial role in plant life, as these elements are necessary for plant growth and development. However, they can also have detrimental effects on plants and the environment. In recent years, research on HMs has gained significant attention and is expected to become a dominant field due to their harmful impact on humans, animals and plants. The phytotoxicity of HMs is influenced by several factors, including the specific metal type, exposure route, dosage, plant age, nutritional status and environmental conditions. Among the most toxic metals to plants, arsenic, cadmium, chromium and lead are considered priority contaminants due to their severe impact on plant health. The current review discusses important HMs, their toxicity mechanisms to the plants and their interactions with special emphasis on the arsenate, cadmium, chromium and lead.

Keywords: analysis; growth; HMs; plants; toxicity

Introduction

The existence of HMs and their toxicity presents a considerable threat to natural ecosystems due to their high toxicity, persistence and tendency to accumulate in living organisms (1,2). HMs can be defined as metallic elements characterized by a density higher than that of water (3, 4). Due to the link between high density and toxicity of HMs, this category also includes metalloids such as arsenic, which can cause harm even at very low levels of exposure (5, 6). The accumulation of HMs in agricultural soils has emerged as a critical global challenge, driven by diverse sources like natural geological formations, landfills, synthetic fertilizers, pesticides, farming practices, industrial emissions and urban contaminants (7).

In biological systems, HMs are categorized as either essential or nonessential. Essential metals like iron, copper, manganese, chromium and cobalt play crucial roles in the physiological functions of living organisms and are required in trace amounts. On the other hand, nonessential metals such as lead, cadmium and mercury serve no known biological function, are highly toxic and are classified as biologically nonessential (8). Nonessential HMs can interfere with several biochemical processes in plants, including nutrient balance regulation, gas exchange, enzyme and antioxidant production, protein metabolism and photosynthesis (9-11).

The phytotoxicity effects of HMs typically has several mechanisms on plant health and life, mostly the generation of Reactive Oxygen Species (ROS), enzyme inactivation and the suppression of antioxidant defences (12, 13). However, certain HMs exhibit unique toxicity patterns by selectively binding to specific macromolecules. Understanding the various toxic mechanisms of HMs enhances the knowledge of their harmful impact on plant physiology, ultimately aiding in the effective management of reducing their impacts (3). This review aims to explore the existing literature on the toxicity of four HMs arsenate, cadmium, chromium and lead providing deeper insights into their detrimental effects plant life.

Arsenic (As)

As is one of the most important and toxic HMs in the world; and annually more than 70 million people are exposed to arsenic poisoning according to the WHO (14, 15). Different chemical forms of arsenic are existing and the species of arsenate (V) (H_2AsO_4-: at pH 2-6); as well as arsenite (III) (H_2AsO_3-: at pH 9-12), are the most dominant As species found in nature (16, 17). Several processes are responsible of arsenic distribution into the environment including weathering; mineral ores; fire; volcanic eruption and industrial activities such as energy production and fossil fuel burning; pesticides manufacturing and many other activities (18, 19, 10).

As is very toxic for human, animals and plants and could one of the causes of cardiovascular failure, neurological and gastrointestinal system abnormalities, liver and kidney dysfunctions (20-23).

As toxicity to the plants health and ecosystems poses significant risk due to its ability to disrupt cellular functions even at trace concentrations by interfering with critical