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Problems of Biotechnological and Agronomic, Breeding Interventions to Mitigate Heavy Metal Toxicity in Agriculture

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Abstract

Global agriculture productivity and output are seriously threatened by heavy metal toxicity, which reduces the potential yield of the main food crops. It lowers seed germination, causes oxidative stress, affects photosynthesis, and degrades physiological function in plants. The heavy metals are absorbed by plants from the polluted soils, and persons who consume the crops cultivated there suffer serious health problems. Humans and activities connected to humans are the main cause of HMT. As a result, it is crucial to address the HMT issue in agriculture. One of the most efficient ways to remove heavy metals from the soil is through agronomic treatments such as bioremediation, which may be done using either plants or bacteria. There have been reports of over 400 plant species acting as hyperaccumulators of different heavy metals. Breeders may create agricultural cultivars resistant to heavy metals by biotechnology and breeding techniques for broader adaption. For a variety of commercially significant food crops, several heavy metal resistant crop cultivars have been created and sold. Utilizing omics, gene editing, and high throughput screening technologies may hasten the production of new cultivars. In order to reduce the HMT problem in agriculture, we thus concentrate on assessing agronomic, breeding, and biotechnological treatments, as well as sensors for heavy metal detection to quicken the screening process.

Keywords: Free radicals; Heavy metals; Hyperaccumulators; Metal toxicity; Metal transport; Oxidative stress; Phytoremediation

Introduction

Animal life, human health, and agricultural output are all seriously threatened by heavy metal poisoning. Some heavy metals are necessary for the development and operation of plants. Heavy metal toxicity in plants is brought on by these metals in excess [1]. Arsenic and other heavy metals accumulate as a result of anthropogenic activity [2]. One of the most significant issues with contemporary crop cultivation is the excessive buildup of heavy metals in soil and water [3]. These harmful metals have become more prevalent in agricultural soils during the past ten years [4]. The group of elements known as heavy metals includes those whose atomic masses are greater than 20 and whose specific gravities are greater than [5]. HMT seriously contaminates the environment and harms the soil, bacteria, plants, animals, people's health, and the agricultural ecology polluted with heavy metals Millions of people's access to food is harmed by water, air, and soil factors that cause low agricultural production and limited crop growth. Simply having better air might increase yields of important crops like maize and soybean by 20% [6]. The harm to human health from heavy metal exposure is also present [7]. Skin lesions, gastrointestinal and renal malfunction, nervous system diseases, vascular damage, immune system dysfunction, birth deformities, and cancer are just a few of the acute and chronic issues it can lead tob [8]. They represent a serious danger to the sustainability of agriculture due to their non-biodegradable, toxic, and persistent bioaccumulation in the food chain [9]. Inadequate treatment of industrial waste, urbanisation, mining operations, transportation emissions, and excessive use of pesticides and fertilisers are all causes of heavy metal buildup in soil [10]. In addition, heavy metal concentrations in soil can be raised by volcanic eruptions, wind-borne soil particles, sea-salt sprays, forest fires, biogenic sources, and rock weathering. Due to chemical effluent wastes, soils in industrial metropolitan centres are typically more contaminated with heavy metals like Pb, Cu, Cd, and zinc. High levels of some heavy metal emissions are linked to specific industrial operations, such as the burning of fossil fuels with vanadium, nickel, cadmium, tin (Sn), and selenium, as well as the use of pesticides that include aspartame and Pb. Low levels of heavy metals do not have significant impacts, however high levels have negative consequences. Several heavy metals, including copper, zinc, iron, manganese, molybdenum, and nickel, are essential for the growth and development of plants. to combat biotic and abiotic stressors, reduce fungal penetration, and lessen insect resistance. Reactive oxygen species are produced when there is an increase in the concentration of heavy metals. Apoptosis, cell structure and membrane rupture, cytoplasmic enzyme inhibition, oxidative stress, and damage to cellular organelles are all results of ROS. Among the naturally occurring elements, 53 have been identified as heavy metals, and the majority of these don't play any vital roles in plants. Although elements like zirconium, antimony, As, Pb, Hg, and Cd do not have any metabolic roles in plants, their presence in soil at very high concentrations as a result of absorption and accumulation in plant parts can significantly lower agricultural output important plant metabolic processes include nutrition and water absorption. The most impacted processes are photosynthesis and nitrogen metabolism. Additionally, by generating ROS, heavy metals alter the redox state of the cell. There have also been reports of diminished root and shoot development, interference with photosynthesis and respiration, and decreased chlorophyll production due to grana structural disorganisation. Thus, it is crucial to comprehend how heavy metal uptake by agricultural plants negatively affects many physiological processes and, eventually, crop output.

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