Chapter 6
Impact of Heavy Metal Stress (Ni and Co) on Maize (Zea mays): Exploring Biochemical and Morphological Responses for Climate Resilience and Sustainability

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ABSTRACT

Heavy metal contamination, particularly from nickel (Ni) and cobalt (Co), is a significant issue in agricultural regions, especially those influenced by industrial activities. This study investigates the impact of Ni and Co stress on maize (Zea mays) by evaluating the plant's morphological, physiological, and biochemical responses to varying metal concentrations. We measured leaf number, leaf length, root length, fresh and dry weights of aerial and root parts, as well as chlorophyll content, proline, total sugars, polyphenols, and flavonoids. The results reveal that higher concentrations of Ni and Co caused notable reductions in growth and alterations in metabolic processes, with increased levels of stress-related markers. This research emphasizes the detrimental effects of heavy metals on maize, highlighting the need for sustainable agricultural practices to mitigate pollution. By understanding the impact of heavy metals on crop health, this study contributes to the broader goal of enhancing food security and improving resilience in regions facing soil contamination challenges.

1. INTRODUCTION

Contamination of soils by heavy metals is an increasingly serious environmental issue around the world, especially in developing countries where industrialization and urbanization often occur faster than environmental regulations can adapt (Silva et al., 2021; Adnan et al., 2022; Oudghiri et al., 2025). Trace elements such as nickel (Ni) and cobalt (Co) are naturally present in the environment but they are now being introduced into our ecosystems at an increasingly significant rate due to anthropogenic activities; including mining, industrial effluents, use of untreated wastewater in irrigation, and excessive application of phosphorous fertilizers that often contain rich trace metals (Boros-Lajszner et al., 2021; Ali et al., 2022; Khan et al., 2023). After entering the environment, these metals can persist in soils for an indefinite time without bioremediating, accumulate in plant tissues, and can finally bioaccumulate in the food chains of both humans and animals (Rajput et al., 2024), creating health and safety concerns in the long term (Kumar et al., 2019; Uddin et al., 2021; Angon et al., 2024; El-Khadir et al., 2024; Mouniane et al., 2025).

When plants are subjected to high concentrations of Ni and Co, they can initiate a vast array of physiological and biochemical perturbances (Emamverdian et al., 2015; Shakespear et al., 2024). These metals affect vital metabolic processes, such as nutrient uptake, photosynthesis, water balance, and catalytic activities. They also induce excessive production of reactive oxygen species (ROS), which induces oxidative stress, membrane damage, and ultimately inhibition of growth or death of plant tissues (Kumar et al., 2022; Liu et al., 2023; Zhao et al., 2023; Wang et