

Abstract

Heavy metal pollution poses serious risks to ecosystems and human health and requires effective monitoring strategies. Therefore, the search for appropriate bioindicators of heavy metal pollution (such as Cd, Pb, Cu, Zn, Ni) among widespread common weeds—rough amaranth (*Amaranthus retroflexus* L.), meadow clover (*Trifolium pratense* L.), common sorrel (*Rumex acetosa* L.), narrowleaf plantain (*Plantago lanceolata* L.), and pink mallow (*Alcea rosea* L.)—was the main aim of the research. Due to the circulation of heavy metals in the environment and the existence of two sources of their uptake by plants, the planned experiments aimed to the comparative assessment of selected species ability to accumulate heavy metals from various sources and tested their physiological response to stress. In the first experiment, to assess the ability of individual weeds to accumulate heavy metals mainly related to air pollution, selected plants were exposed at urban sites near reference measurement stations. The results showed a varied but generally high potential for the accumulation of individual heavy metals and an adequate level of physiological response and activity of the defense system in response to stress. Increased H₂O₂ content, increased levels of enzyme markers catalase (CAT) and ascorbate peroxidase (APOX), and a marker of membrane lipid peroxidation—malonaldehyde (MDA) were detected in both roots and leaves. There was also a significant reduction in the values of photosynthetic activity parameters, such as net photosynthetic intensity (P_N), stomatal conductance (g_s), and intercellular CO₂ concentration (C_i). Due to the movement of heavy metals from the air into the soil, the second experiment was conducted under controlled conditions. Its aim was to assess the accumulation of Cd, Pb, Zn, and Ni ions from the soil solution in the plants tested in the first experiment. *T. pratense* showed to be an indicator showing consistent effectiveness in the accumulation of Zn, Ni, and Cd ions, *P. lanceolata* proved to be an indicator of Zn and Cd contamination, with an adequate increase in the activity of stress markers in the leaves and roots of both species. In the third on-site bioindication investigation, the effectiveness of *T. pratense* as a bioindicator of pollution was assessed in various areas of the city agglomeration, and therefore in habitats diversified in terms of air pollution and edaphic aspects. The detected very high levels of bioconcentration (BCF) and translocation (TF) of the tested elements in plants, adequate to the level of contamination, suggest a high potential of meadow clover as a bioindicator of heavy metal contamination in urban areas with different land uses. Summarizing the results of the conducted experiments, *T. pratense* and *P. lanceolata* are recommended for environmental monitoring and assessment, providing information on the level of heavy metal pollution in various ecosystems.

Keywords: heavy metal pollution, bioindicators, weed species, physiological stress responses

