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Lead and Arsenic Accumulation in Safflower: A Phytoremediation Study

Vinita Dheeran

dheeran1982@gmail.com
Department of Botany M.M.H. College, Ghaziabad (Uttar Pradesh)

ABSTRACT

The present study explores phytoremediation, a technology that utilizes plants to absorb and detoxify environmental contaminants, particularly heavy metals and organics. It discusses the historical context of using plants for wastewater treatment and presents findings on the accumulation of lead and arsenic in safflower (Carthamus tinctorius L.) as a remediation strategy.

Key words: Safflower, Phytoremediation, Heavy metal.

1. INTRODUCTION

The importance of metal-accumulating plants in environmental cleanup is becoming evident with the development of a new technology called 'phytoremediation.' This approach involves plants absorbing, accumulating, detoxifying, or neutralizing contaminants in their growth mediums such as soil, water, and air through physical, chemical, or biological means [1,2]. Utilizing the roots of terrestrial plants to extract organic compounds or heavy metals from water solutions could lay the groundwork for an innovative water treatment method. This technique could potentially be applied to treat surface and groundwater, as well as industrial waste, to lessen contaminant levels. Economically, plants that promote organic breakdown or gather toxic metals can be cultivated and harvested, significantly reducing toxic chemical contamination in soil or water. The idea of using plants for environmental cleanup is not new; about 300 years ago, plants were first suggested for wastewater treatment [12,17]. By the late 19th century, Thlaspi caerulescens and Viola calaminaria were the first plant species recorded to accumulate high metal concentrations in their leaves [8,9]. Research has shown that plants can accumulate up to 1% nickel in their shoots, with Thlaspi caerulescens also noted for high zinc accumulation [7,10,19]. Currently, Brassica species are gaining attention for their metal accumulation abilities. Studies on various B. juncea (Indian mustard) varieties have demonstrated their capacity to absorb and concentrate toxic metals to several percent of their dried shoot biomass. Certain sunflower (Helianthus annuus) varieties are the most efficient for rhizofiltration.

2. MATERIALS AND METHOD

In the current study, the focus was on the accumulation of two heavy metals, lead (Pb) and arsenic (As), in safflower (Carthamus tinctorius L.), a significant dicotyledonous oil crop. Lead acetate and sodium arsenate served as the sources of lead and arsenic, respectively. Safflower accessions, obtained through the All India Coordinated Research Project on Oil Seeds (AICRPO), and the National Bureau of Plant Genetic Resources (NBPGR), were evaluated for their response to these metals. Stem cuttings of consistent thickness and length were cultured in a 10^{-3}M solution of lead and arsenic, prepared using Hoagland's solution. Control groups were grown in Hoagland's solution without lead and arsenic. To measure the accumulation of lead and arsenic in safflower, root and mature leaf samples were collected after eight days of hydroponic growth in 10^{-3}M lead acetate and sodium arsenate. The samples, consisting of 100 mg of oven-dried roots and leaves, were digested in 5 ml of a 1:1 mixture of concentrated nitric acid (HNO_3) and perchloric acid ($HClO_4$) until fully digested and the liquid evaporated. The resulting digested material was dissolved in 10 ml of double distilled water. The accumulation of lead and arsenic was then determined using an Atomic Absorption Spectrometer.

3. RESULT

When exposed to lead, all the accessions could accumulate this metal in both their roots and mature leaves. Nevertheless, the lead concentration was more pronounced in the roots than in the mature leaves (Fig. 1). Similarly, accessions treated with arsenic showed comparable outcomes, with arsenic levels being higher in the mature leaves than in the roots (Fig. 2). The presence of lead and arsenic in mature leaves suggested that, for most accessions, these elements could be transported from the roots to the shoots. Given that the safflower accessions varied in their genotypes, these observations implied that both the accumulation and the movement of lead and arsenic from root to shoot were influenced by genotype.

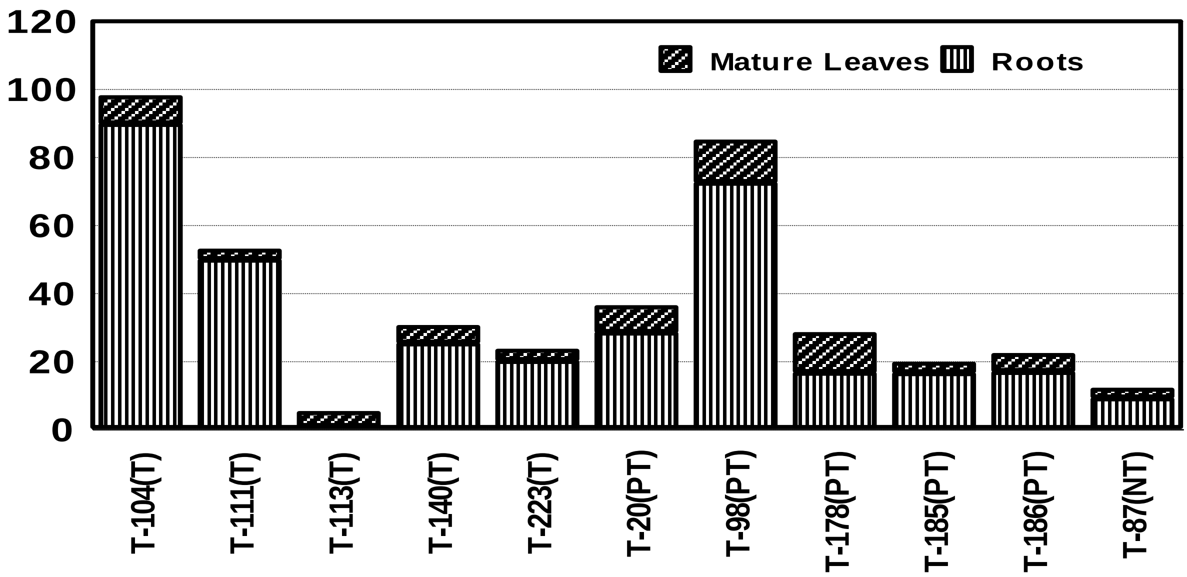

Figure 1. Graph showing lead buildup in roots and mature leaves.

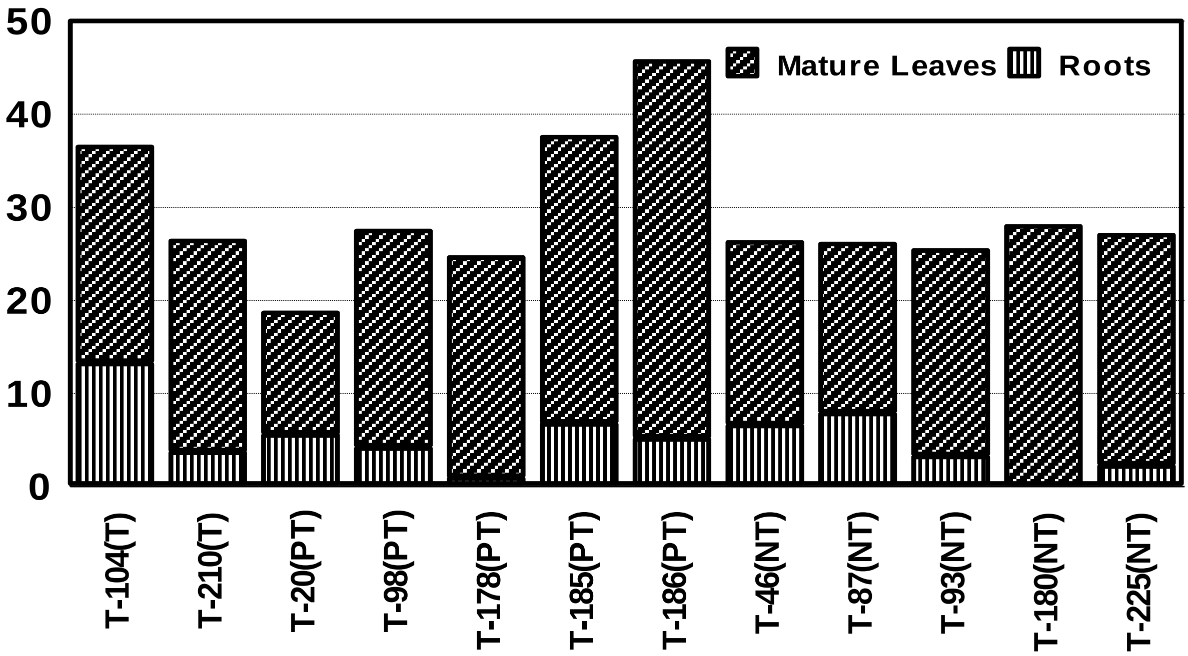

Figure 2. Graph showing arsenic buildup in roots and mature leaves.

4. DISCUSSION

Metal accumulation is acknowledged as a significant physiological adaptation for tolerating heavy metals [13,14]. The extent of metal accumulation varies, from a slight increase above the 'background' level to an extreme scenario where metal content can exceed 1% of the plant's dry weight. The chemical form of the element in solution also influences how much metal plants accumulate. Accumulator plants can concentrate metals in their aboveground parts to a remarkable extent, regardless of whether the substrate concentration is low or high [4,5,6]. An accumulator is defined as a species whose metal concentration surpasses the typical levels found in plants for a specific substrate [11,18]. Studies of plant parts indicate that accumulators generally tend to move most of the absorbed metal from the roots to the shoots. [15,16] Consequently, the metal concentrations found in the aerial parts of the plant are usually much higher than those in the roots [20].

- **Extreme physiological response:** Metal accumulation is recognized as an extreme type of physiological response in heavy metal tolerance. The degree of accumulation can vary from a small elevation above background levels to an extreme response where a metal might constitute over 1% of plant dry matter.

- **Chemical form dependency:** The accumulation of metals by plants depends on the chemical form of the element in solution. Accumulators are capable of concentrating metals in aboveground parts to an extraordinary degree, regardless of substrate concentration.

- **Translocation tendency:** Analysis of plant parts suggests that accumulators tend to translocate most metals taken up from roots to shoots, resulting in higher concentrations in aerial parts compared to roots.

5. SUMMARY

This document discusses the potential of phytoremediation, a technology where plants absorb and detoxify environmental contaminants, particularly focusing on heavy metals and organics. It highlights the historical context of using plants for wastewater treatment and presents findings from an investigation into the accumulation of lead and arsenic in safflower (Carthamus tinctorius L.) as a method for environmental remediation.

- **Phytoremediation benefits:** The document outlines how plants can effectively reduce toxic chemical contamination in soil and water, emphasizing the economic viability of cultivating plants like Brassica species and sunflower for metal accumulation.
- **Experimental findings:** Results from the investigation indicate that safflower can accumulate lead and arsenic, with higher concentrations found in roots for lead and in mature leaves for arsenic. The translocation of these metals from roots to shoots varies by genotype, demonstrating the importance of genetic factors in metal accumulation.

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