Helianthus annuus assessment for nickel phytoremediation

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Abstract

Heavy metals (HMs) are distributed in various forms within the soil, including dissolved in the soil solution, adsorbed on soil constituents, and associated with organic matter (Shuman, 1991). HMs pose serious environmental threats due to their persistence and toxicity (Gu et al., 2018; Wang et al., 2020). They accumulate in soil and organisms through natural processes and human activities like mining, pesticide use, inadequate waste management, and industrial practices contribute significantly. (Brodin et al., 2017; Ferrey et al., 2018).
Exposure to heavy metals can lead to a range of health issues, including neurological disorders and organ damage. Lead, for example, can cause appetite loss and renal dysfunction, mercury toxicity results in neurological symptoms like tremors and cognitive loss, and organic mercury compounds pose health risks, nickel causes vomiting, nausea, headache, and, in more severe cases, gastric hemorrhage (Guzzi et al., 2020).
Therefore, it is important to develop remediation technologies for soils contaminated by heavy metals.
Phytoremediation is a technique that utilizes plants to absorb, transfer, or transform pollutants and emerges as a green and effective method for environmental cleanup. It addresses soil, water, and sediment contamination caused by heavy metals, organic pollutants, and even radioactive elements. The process involves absorption, volatilization, degradation, and stabilization by plants to eliminate or immobilize pollutants, offering promise for environmental purification (Lin et al., 2021; Singh et al., 2016). This technique encompasses various approaches categorized into phytoextraction, phytostabilization, phytovolatilization, phytofiltration, and phytotransformation. Phytoextraction involves plants accumulating heavy metals in their shoots without altering soil properties, enabling the removal of pollutants from polluted environments. (Al-Baldawi et al., 2018).

Several factors influence phytoremediation efficacy, including the choice of plant species, soil characteristics, rhizospheric microbial communities, climatic conditions, and heavy metal bioavailability. The bioavailability of heavy metals, affected by soil pH, moisture, organic matter, and oxygen levels, directly impacts phytoextraction efficiency. Heavy metals in soils are categorized into available, unavailable, and exchangeable fractions, with pH playing a crucial role in their dissolution. Alkaline pH reduces metal bioavailability due to low dissolution rates, highlighting the intricate interplay between soil chemistry and phytoremediation effectiveness (Ashraf et al., 2019; Javed et al., 2019; Wei et al., 2008).

In this study, the evaluation of Helianthus annuus's potential in phytoremediation has been assessed, considering two polluted pots irrigated with 80 mgCu/L and 40 mgCu/L in a continuous irrigation rate of 1.644 mm/day for 12 weeks.

The tolerance and phytoextraction capacity for nickel has been evaluated, and the overall phytoextraction potential has been evaluated considering bioaccumulation and translocation factors.

The Nickel tolerance test, depicted in Figure 1, shows Helianthus annuus' varying tolerance to Nickel concentrations. The difference in growth between the two pots is notably evident after the sixth week, with a considerable decrease observed in Pot 1, attributable to the high concentrations of Nickel. Tolerance to the pollutant constitutes a key factor in implementing phytoremediation interventions. Having approximate knowledge of the pollutant's limit concentrations allows for better evaluation of the species to be used for the remediation intervention.

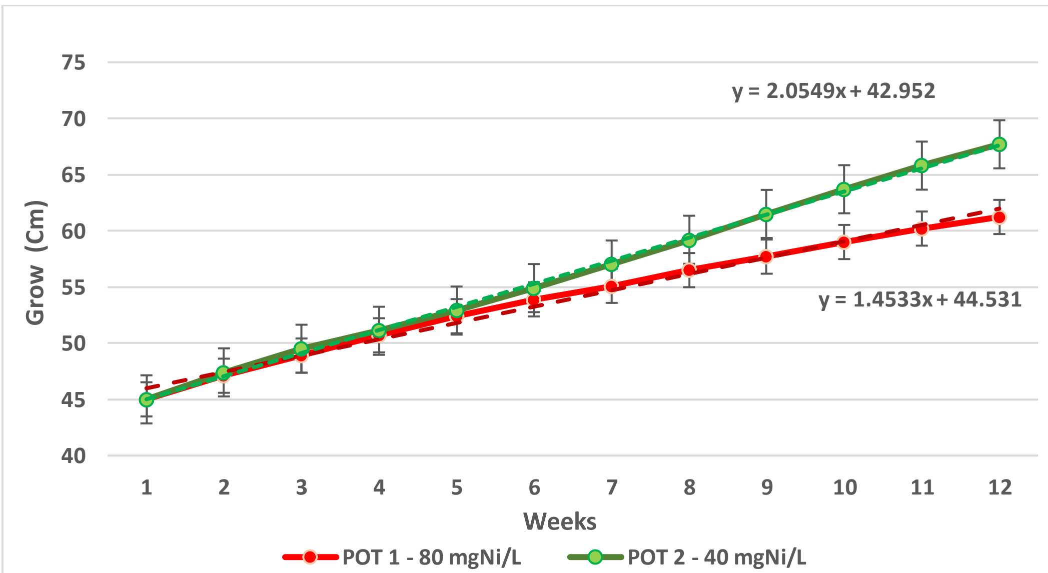

Figure 1. Tolerance test of Helianthus Annuus evaluated with 80 mgNi/L and 40 mgNi/L in contaminated water.

Figure 2 illustrates the nickel concentrations in underground tissues and aerial tissues after 12 weeks of phytoextraction test. The phytoextraction test aims to determine the concentrations of pollutants in the various plant tissues, thereby enabling proper assessment of the species' adaptability to the correct phytoremediation technology.
These data illustrate a direct correlation between environmental nickel concentration and its uptake and accumulation in plant tissues. Primarily acting as the main absorption site from the soil, roots exhibit the highest concentrations, followed by stems and leaves. These findings underscore Helianthus annuus's capability to accumulate nickel from its surroundings, particularly in roots, intensifying accumulation as the surrounding soil or water nickel concentrations elevate.

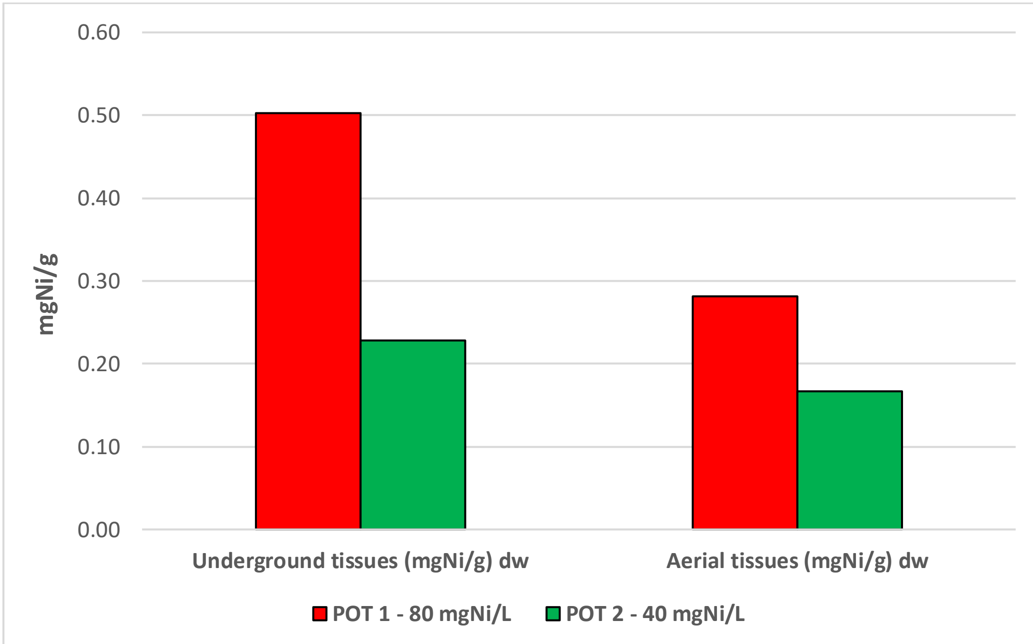

Figure 2. Phytoextraction test of Helianthus Annuus evaluated with 80 mgNi/L and 40 mgNi/L in contaminated water after 12 weeks.

To evaluate the phytoextraction capacity of Helianthus annuus the bioconcentration factor (BCF) and translocation factor (TF) have been determined. BCF of metals is an index of the ability of the plant to accumulate a particular metal concerning its concentration in the soil. TF represents the ratio of nickel concentration in the aboveground plant parts to the nickel concentration in the root and rhizome system (Buscaroli 2017).
At concentrations of 40 mg/L and 80 mg/L, the bioconcentration factors were found to be 1.03 and 0.86, respectively. Corresponding translocation factors were determined as 0.73 and 0.56, respectively. These results suggest that Helianthus annuus possesses a moderate ability to accumulate metals in its tissue compared to the concentration in the surrounding soil. However, it exhibits limitations in translocating metals from roots to aboveground parts. Helianthus annuus demonstrates varying levels of tolerance towards different concentrations of nickel, which has implications for its efficacy as a phytoremediation agent. The results suggest that as environmental nickel concentrations rise, so does the uptake and storage of nickel in plant tissues, particularly in the root system. In the tolerance assessments, a more pronounced correlation between nickel concentration and observed effects is evident only at 80 mg/L, indicating the existence of a tolerance threshold between 80 and 40 mg/L of nickel. Nonetheless, the plant's capacity to transport and store nickel diminishes at higher concentrations, indicating a limitation in its ability to remediate effectively.
From the results obtained, it can be stated that Helianthus annuus appears to be a good species for the remediation technology of phytoextraction in Apulian heavy metals polluted soils.

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