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Research Article

Assessment of Phytoremediation Potential of Three Weed Plant Species in Soil Contaminated with Lead and Chromium

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The study aimed to compare the tolerance capacity of *Cyperus iria*, *Achyranthes aspera*, and *Eruca sativa* to lead-contaminated and chromium-contaminated soils and to check their phytoremediation potential by pot culture experimentation. The experiment was conducted in three replicates in pots having 4 kg of sieved soil mixed with different doses of chromium, 0, 50, 100, 150, 200, 250, 300, and 350 $mg\cdot kg^{-1}$, and lead, 0, 100, 200, 300, 400, 500, 600, 700, and 800 $mg\cdot kg^{-1}$. The experiment was conducted for 80 days, and roots were harvested two times, i.e., at 40 days and 80 days after sowing. Metal accumulation in the roots was determined by the atomic absorption spectrophotometry method. The result of the study indicated that *C. iria* has the maximum potential to accumulate both the metals in its roots than other two plants. The order of chromium metal accumulation was found to be *C. iria* > *E. sativa* > *A. aspera*. On the other hand, the order of lead metal accumulation was found to be *C. iria* > *A. aspera* > *E. sativa.*

1. Introduction

Environmental pollution is one of the major problems in today's world. Different components of the atmosphere are being polluted by different sources of pollutants. Amid all kinds of pollutants, heavy metals are major contributors to the environmental pollution [1]. Among various heavy metals, As, Cd, Pb, Hg, Cr, and Zn are more toxic. The metals present in soil can easily enter the food chain through crops and can pose risk to humans, animals, plants, and other organisms [2]. Heavy metals persist in the environment for longer periods as they are nonbiodegradable.

Due to their persistent nature, they get accumulated in plants and produce various toxic symptoms in them. Different methods are adopted by scientists to deal with the problem of heavy metal pollution. Phytoremediation is one such approach introduced in the last decade. It is the use of plants to decontaminate the soil from toxic metals. Researchers have found various crop plants that can act as hyperaccumulator and can accumulate toxic metals in their harvestable parts that can be removed afterwards. In a study, it was reported that *Brassica juncea*has the capacity to uptake 500 mg/L of Pb [3]. As these crop plants are consumed by human beings, thus some amount of heavy metals can enter into their body through the food chain.

To overcome these limitations, scientists are showing an interest towards the use of wild weeds for heavy metal removal. They can grow in any type of environmental conditions without the use of synthetic fertilizers. If grown in heavy metal polluted sites, they produce large biomass without much damage. They also grow very fast and are easy to harvest. Many researchers have carried out research works on wild weeds and studied their heavy metal accumulation nature [4–12].

Different workers define weeds differently. Anything that does not require much care for growth may be regarded as weed. Weeds are the plants that are undesirable in a particular place or the plant growing where it is not wanted. Some of the characteristics of weeds are abundant seed production, rapid population, long time survival, high adaptability, and capacity to grow in human populated urban places.

A study was done on phytoremediation potential of a weed *Amaranthus spinosus* by using various concentrations of heavy metals such as Cu, Zn, Cr, Pb, and Cd in which the biological concentration factor (BCF) and translocation factor (TF) were more than 1 showing that *Amaranthus spinosus* is a good agent for heavy metal accumulation [13]. In a study, the phytoremediation capacity of *Solanum nigrum*, *Euphorbia hirta*, *Amaranthus hybridus*, and *Xanthium strumarium* weeds against Cd, Pd, and Ni on contaminated lands was studied and it was found that these weeds grow well in contaminated soils and produced more antioxidant enzymes and are good for restoring contaminated areas [9]. Pot culture experimentation was done using three weed plant species, i.e., *Acalypha indica*, *Abutilon indicum*, and *Physalis minima* for their ability to accumulate Pb, Ni, Cd, and Cr from contaminated soils. The results showed that *A. indica* accumulated Pb, Ni, and Cr, *A. indicum* accumulated Cr, and *P. minima* accumulated Pb and Cr. Thus, all weeds can be recommended as good agents for remediation of contaminated soils [14].

Comprehensive research has been carried out in past decades about the capability of wild weeds for their considerable potential to accumulate various heavy metals in their roots, stems, and vegetative parts. The use of native weed species has been gaining importance for region-specific phytoremediation operations and is establishing itself as a significant tool for green removal of contaminants. These native species are enormously capable for enhanced phytoextraction owing to their greater adaptability towards region-specific environmental conditions. The present work was designed taking all these factors in consideration, and three weeds were chosen and further compared for their phytoremediation ability for lead-contaminated and chromium-contaminated soils by pot culture experimentation. The chosen weeds were *Cyperus iria*, *Achyranthes aspera*, and fodder plant *Eruca sativa*, which are extensively and successfully grown in the Punjab state of Indian subcontinent and have earlier never been explored for their metal-accumulating ability for remediation purposes.

2. Materials and Methods

2.1. Pot Experiment. Pot experiment was conducted under natural field conditions using two heavy metals. Pots were prefilled with 4 kg of grounded, sieved soil free from heavy metals. The texture of the soil was loamy sand with pH values between 7.8 and 8.0. Three weed species, i.e., *Cyperus iria*, *Achyranthes aspera*, and *Eruca sativa*, were used as test plants during the study. The seeds from identified plants were used to grow the plants for the experiment. Matured plants of these weeds were collected in the flowering stage from the Jalandhar region, Punjab (31.265494°N, 75.702605°E), from wild areas. All the plants were authenticated on the basis of morphological characters by taxonomy experts at Lovely Professional University. The voucher specimens of *Cyperus iria* (no. 02102018), *Achyranthes aspera* (no. 02602018), and *Eruca sativa* (no. 02902018) were prepared and deposited in the Department of Botany, Lovely Professional University, Phagwara, Punjab, India. Before sowing the seeds, soil was mixed with different doses of Cr and Pb metals. Different concentrations of Cr used were 0, 50, 100, 150, 200, 250, 300, and 350 $mg \cdot kg^{-1}$, and different concentrations of Pb used were 0, 100, 200, 300, 400, 500, 600, 700, and 800 $mg \cdot kg^{-1}$. The experiment was carried out in triplicates in a completely randomized design.

2.2. Analysis of Metals. Plants with metal treatment were harvested 40 days after treatment (DAT) and 80 days after treatment (DAT) for the analysis of metal uptake. The procedures adopted for this were as follows:

2.2.1. Elemental Analysis. The uptake of Cr (VI) and Pb (II) in the roots of all the plants was carried out from the Department of Soil Sciences, Punjab Agricultural University, Ludhiana, by using inductively coupled plasma-atomic emission spectrometry (ICP-AES) (model Avanta GBC GF 3000 system, GBC Scientific Equipments, Australia) via the wet digestion method.

2.2.2. Sample Preparation. The dried plant samples were digested by the method given by Allen et al. [15]. The samples were weighed (0.4 g) and put in digestion beakers. The digestion mixture consisted of nitric acid (HNO_3) and perchloric acid ($HClO_4$) in the ratio of 2 : 1. In the digestion beaker, 5 mL of the digestion mixture was initially added and heated. The addition of the acid mixture was continued until the solution of the digested plant sample became clear. After digestion was complete, the final volume of the sample was made upto 50 mL with distilled water and strained with Whatman No. 1 filter paper. The samples were then stored in glass vials at −20°C for further use.

2.3. Calculations. Let the concentration of the analyte observed = x ppm (*i.e.*, x mg of Cr (VI) in 1000 mL of the solution). Therefore, y mL of the solution contains = $xy/1000$ mg of Cr (VI). Let y mL of the solution be prepared from "w" g of the plant material. Then, 1 g of the plant material contains = $xy/1000w$ mg/g of Cr (VI). Let the final volume of the sample prepared after digestion = y mL. The same procedure and calculations were repeated for the analysis of lead.

2.4. Statistical Data Observation. All the calculations were carried out in triplicates. The calculation of mean and standard deviation was also carried out for all the values. One-way ANOVA was performed to analyze the data statistically by using the method developed by Bailey [16]. Data were shown as mean ± S.D of triplicates using Tukey's multiple comparison test, significant at $^{****}p \leq 0.0001$, $^{***}p \leq 0.001$, $^{**}p \leq 0.01$, and $^{*}p \leq 0.05$. p values ≤0.05 were considered significant for comparison purposes. The calculations were carried out using GraphPad prism software version 8.4.1.

3. Results

3.1. Chromium Uptake in the Roots of Three Weed Species. In all the three weed species, metal-absorbing capacity gets increased with an increased dose of chromium (Figures 1–3). In *C. iria*, metal uptake was maximum at 350 mg·kg^{-1}of Cr concentration in both 40 and 80 days old plants with accumulation of 1.34 and 1.64 mg/g DW, respectively. Metal uptake in *E. sativa* plants at 350 mg·kg^{-1} concentration of Cr in 40 and 80 days old plants was 1.16 and 1.2 mg/g DW, respectively. In case of *A. aspera*, the rise in the level of metal uptake was higher at 350 mg·kg^{-1} Cr concentration, but the increase was mostly nonsignificant in both 40 and 80 days mature plants. Also, the metal was nondetectable at 50 mg·kg^{-1} Cr concentration in *A. aspera* plants.

3.2. Lead Uptake in the Roots of Three Weed Species. Same as with chromium, lead uptake ability in all the three species increased with increase in the concentration of lead heavy metal (Figures 4–6). In *C. iria*, lead accumulation was maximum in roots of plants grown at 800 mg·kg^{-1}, in both 40 and 80 days old plants, and this increase was 1.88 and 1.96 mg/g DW, respectively. F-ratio was found to be significant in *E. sativa*; lead metal absorbing potential was again maximum at 800 mg·kg^{-1} concentration of lead, and this accumulation was 1.27 mg/g DW in 40 days old plants and 1.61 mg/g DW in 80 days old plants. In case of *A. aspera*, metal-absorbing capacity was 1.19 mg/g DW in 40 days old plants and 1.94 mg/g DW in 80 days old plants at 800 mg/kg of Pb concentration in contrast to plants taken as control. F-ratio was found to be significant.

In comparison between three species on common concentrations (100, 200, and 300 mg·kg^{-1}), it was observed that all the species showed the same pattern of accumulation for heavy metals as the concentration of heavy metals increased. The results further showed that *C. iria* accumulated more Cr (VI) than Pb (II) at all concentrations. In *Eruca sativa*, much difference was not found at 100 and 200 mg·kg^{-1}, but at 300 mg·kg^{-1}, Cr (VI) was accumulated more (0.83 mg/g DW 40 DAT and 1.20 mg/g DW 80 DAT) than Pb (0.25 mg/g DW 40 DAT and 0.53 mg/g DW 80 DAT). *Achyranthes aspera* showed comparably similar accumulation at all concentrations for both heavy metals.

4. Discussion

In the present study, metal uptake by the roots of the plants was observed because roots act as barriers for upward movement of the metal into other parts of the plant [17]. Comparison of tolerance capacity to lead and chromium heavy metals in three weeds *Cyperus iria*, *Achyranthes aspera*, and *Eruca sativa* was studied. It was done by planting them in different concentrations of heavy metal-contaminated soils in order to check their phytoremediation potential. All three species showed an increase in absorption with an increase in concentration of heavy metals. In *C. iria*, metal uptake was observed to be maximum at 350 mg·kg^{-1} Cr concentration and 800 mg·kg^{-1} Pb

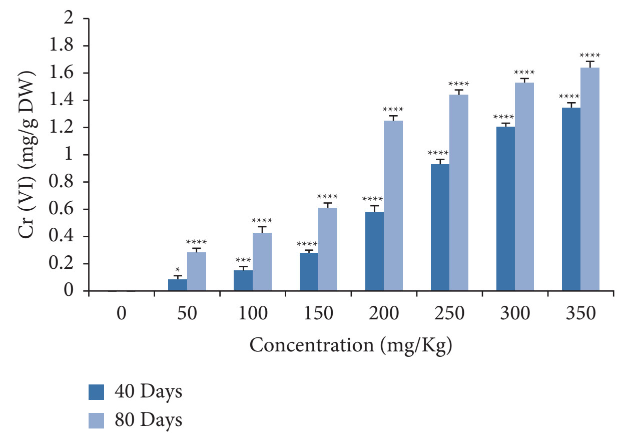

Figure 1: Effects of Cr (VI) uptake in 40 and 80 days old *C. iria* plant roots (40 days F-ratio (df 7, 16): 932**** and HSD: 0.084; 80 days F-ratio (df 7, 16): 992.8**** and HSD: 0.099).

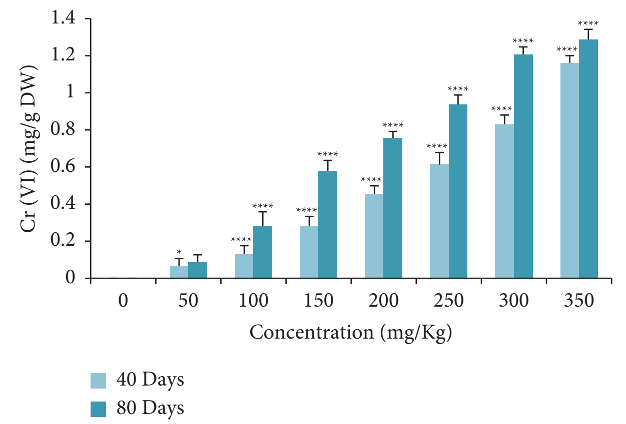

Figure 2: Effects of Cr (VI) uptake in 40 and 80 days old *E. sativa* plant roots (40 days F-ratio (df 7, 16): 237.9**** and HSD: 0.128; 80 days F-ratio (df 7, 16): 306.1**** and HSD: 0.137).

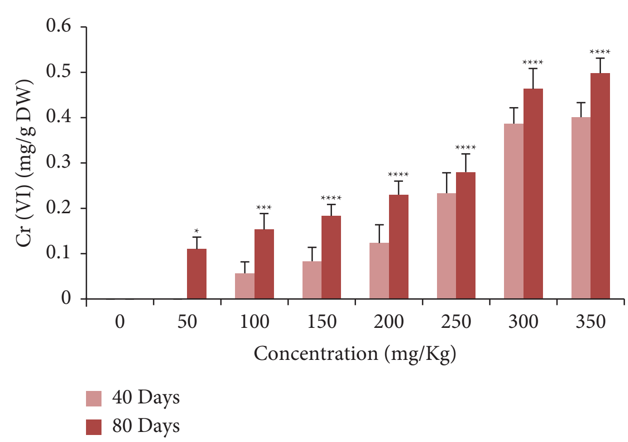

Figure 3: Effects of Cr (VI) metal uptake in the roots of 40 and 80 days old *A. aspera* plants (40 days F-ratio (df 7, 16): 55.27**** and HSD: 0.089; 80 days F-ratio (df 7, 16): 62.68**** and HSD: 0.089).

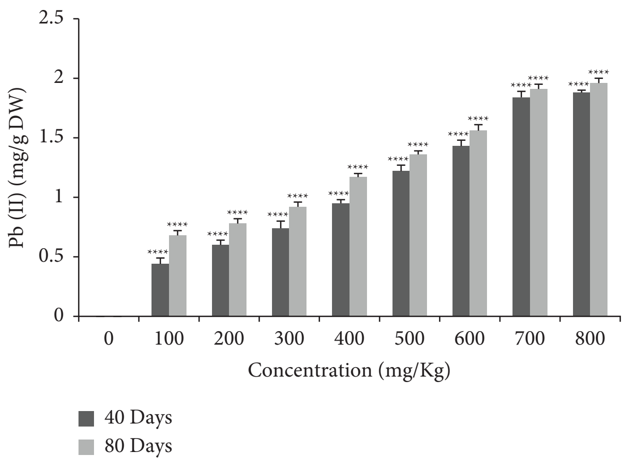

Figure 4: Effects of Pb (II) metal uptake in the roots of 40 and 80 days old *C. iria* plants (40 days F-ratio (df 7, 16): 797.2**** and HSD: 0.11; 80 days F-ratio (df 7, 16): 1008**** and HSD: 0.094).

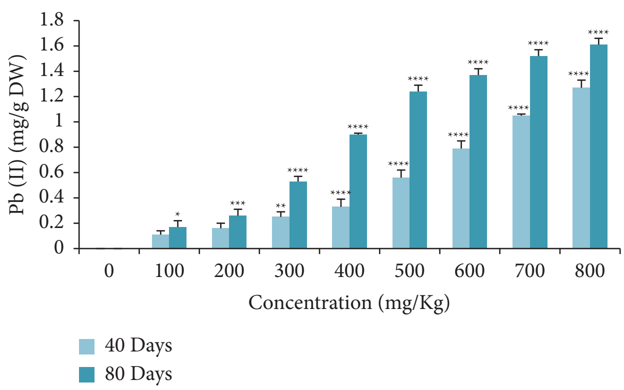

Figure 5: Effects of Pb (II) metal uptake in the roots of 40 and 80 days old *E. sativa* plants (40 days F-ratio (df 7, 16): 176.3**** and HSD: 0.166; 80 days F-ratio (df 7, 16): 375.7**** and HSD: 0.159).

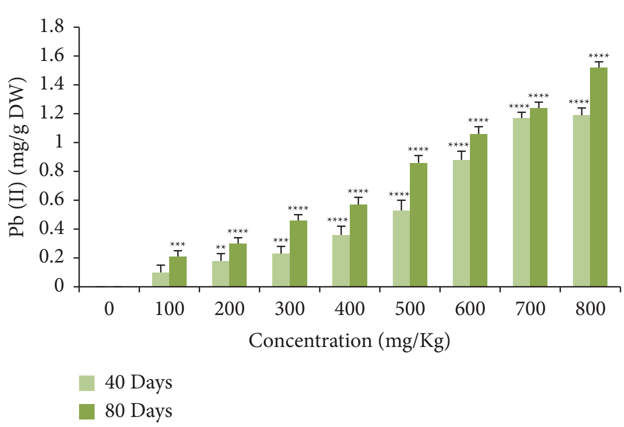

Figure 6: Effects of Pb (II) metal uptake in the roots of 40 and 80 days old *A. aspera* plants (40 days F-ratio (df 7, 16): 271.7**** and HSD: 0.137; 80 days F-ratio (df 7, 16): 467.2**** and HSD: 0.118).

concentration in both 40 and 80 days old plants. Similar results were found by Shahanaz and Ramakrishna, who studied the accumulation of heavy metals in some weed species and found that metal uptake in the roots was more than that in shoots in all the test plants [18]. Zhao and Duo also found more metal content in the roots than in stems and leaves [19]. This is because the cations of heavy metals are less mobile in plants, and thus, after uptake by the plant, they are mainly accumulated in the roots. Absorption beyond a certain level could have a negative implication in different plant parts [17].

5. Conclusion

From the study, it was clear that from all the three selected weed plants, *C. iria* showed maximum absorption of chromium and lead metals in its roots than *E. sativa* and *A. aspera*. Thus, the order of chromium metal accumulation was found to be *C. iria* > *E. sativa* > *A. aspera*. For lead metal accumulation, this order was *C. iria* > *A. aspera* > *E. sativa*. Therefore, it can be concluded that all three weeds can be used for phytoremediation; however, *C. iria* showed more potential.

Data Availability

All the data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors' Contributions

Anand Mohan and Tabarak Malik designed the work. Narinderjeet Kaur collected the data and drafted the article. Sabreen Bashir, Agrataben Vadhel, and Madhuri Girdhar drafted the article and made critical revisions. Narinderjit Kaur and Sabreen Bashir have made equal contributions in the paper for first authorship.

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