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Phytoremediation of Chromium-Contaminated Soil by an Ornamental Plant, Vinca (*Vinca rosea L.*)

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Abstract: Remediation of chromium (Cr) from contaminated soil is an environmental efficient, cost effective modern applicable technique. Phytoremediation potential of an ornamental plant Catharanthus roseus (*Vinca rosea*) was assessed through pot experimentation for chromium contaminated soil. Plants were grown in pots having soils with different levels of chromium contamination i.e. T_1 (10 ppm), T_2 (20 ppm), T_3 (30 ppm), T_4 (40 ppm), T_5 (50 ppm), and T_6 (60 ppm). Plants were also grown in pots with uncontaminated soil as control treatment (T_0). After pot experimentation of six weeks, plants were harvested and plant samples were prepared for the measurement of physical parameters (plant height, fresh and dry weight) and analysis of chemical properties. Soil was collected from the pots to prepare representative soil samples for chemical analysis. Atomic Absorption Spectrophotometer (AAS) was used to measure concentration of Chromium in both plant and soil samples. The results indicated that plant height, fresh and dry weight increased at low concentration, but decreased with high contamination levels of chromium. Translocation factors were found to be lower than 1 for low level of contamination but found to be higher than 1 for higher level of contamination. Concentration of Chromium in plant increased gradually from T_1 to T_3 and became almost same for higher contamination levels (T_4-T_6).

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1. Introduction

Heavy metal contamination of soil and water alters the quality of drinking water, food and ecological environment (Waseem et al. 2014). In developing countries like Pakistan, application of effluent waste for irrigation of crops causes accumulation of many heavy metals in soil (Masood et al. 2012). The ecological risk from heavy metals in soil is growing drastically (Zhao, 2012). These heavy metals such as Cr, Ni, and Cd are taken up by the plant body and potential risk for accumulation in human body increases (Hough et al., 2004; Najam et al., 2015). The heavy metals in higher concentrations have a strong toxic effect on the living organisms and thus known as environmental pollutants (Nedelkoska and Doran, 2000; Chehregani et al., 2005). Most of the heavy metals have toxic effect on human neutrophils (Mushtakova et al. 2005).

Chromium is a major toxic material produced from leather tanneries. It is an emerging environmental challenge which causes different kinds of cancer (Nazir and Bareen, 2008). Chromium in its hexavalent form is carcinogenic especially effecting lungs, liver, and kidney. It is also responsible for DNA damage.

Phytoremediation is an emerging technique used for removal of Heavy Metals from soil which is much cheaper and requires less technical knowledge and skills as compared to other heavy metal removal techniques. Selection of plant for phytoremediation depends upon the ability of plant for extracting heavy metals, their ability to tolerate higher concentrations of heavy metals, easy to harvest, and compotation growth. These plants are highly adapted to accumulate toxic trace metals while growing rapidly in contaminated soils (Ahmadpour, 2012).

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Some plants have ability to uptake and absorb heavy metals from soil along with other nutrients. These are known as hyper accumulators. Phytoextraction, a technique which is also known as phytoaccumulation, phytoabsorption or phytosequestration is a phenomenon in which the contaminants are taken up by the roots of plants and translocated and absorbed by shoot or other above ground biomass like stem, leaves and fruits (Sekara et al., 2005; Yoon et al., 2006; Rafati et al., 2011). *Vinca rosea* is efficient in removal of heavy metals from the soil (Pandey et al. 2007; Subhashini and Swamy, 2013). Phytoremediation is also known as green technology, which is used to clean wastewater and remove contaminations from soil. This technology gains its popularity, as it is cost effective, environmental friendly and adds aesthetic value to the area. Secondly, this technique is equally applicable for removal of organic and inorganic pollutants from soil, air and water. This technique is most publically acceptable (Meagher, 2000; Alkorta and Garbisu, 2001; Garbisu, et al., 2002).

The phytoremediation potential of another ornamental plant i.e. *Zinnia elegance* indicated that the plants grown in lead and chromium were healthier and have bioaccumulation factor greater than 1 for both lead and chromium concentrations up to 60 ppm (Ehsan et al. 2016).

2. Materials and Methods

2.1 Soil Preparation and Characteristics

Soil collected from the field was prepared for pot experiments by air drying, crushing and sieving (mesh size 2mm) to remove stones, wood particles and other undesired contaminants. The soil was thoroughly mixed to make the samples homogeneous for experiment.

Different techniques were used to determine the particle size distribution by hydrometer method (Sheldrick and Wang, 1993), soil texture by textural triangle (Hillel, 1998), Soil bulk density by core method, Conductivity by EC meter (Rhoades, 1989), cation exchange capacity (CEC) by ammonium acetate method (Hendershot et al., 2008) and soil organic carbon and organic matter by wet oxidation or walkley-black method (Nelson, 1982).

2.2 Experimental setup and treatment levels

The prepared soil samples were filled in polythene lined earthen pots having dimensions 45.72 cm height and 30.48 cm diameter. All pots were filled with the same calculated quantity (6 kg) of prepared soil.

The calculated amounts of potassium chromate were dissolved in water to develop the required level of contamination. The prepared solutions of chromium were applied to the soils in pots to develop chromium levels of contamination. The prepared solutions were applied slowly to avoid overflow from the pots. After solution application, pots were left for a few days and then equal amount of water was applied to pots for uniform contamination of chromium in the soil in the pots.

2.3 Plant species and experimental design

Phytoremediation study was conducted on a locally available summer ornamental plant *Vinca rosea* in earthen pots. This species was selected on bases of its easy availability and its good growth rate. This species is tolerant to Chromium. The experiment consisted of 7 treatments and three replications were developed for each treatment. The phytoremediation potential of *Vinca rosea* assessed for lead (Pb) concentrations in a pot study indicated that lead can be efficiently removed through soil in lower concentrations, however it can tolerate the higher concentrations up to 90 ppm (Ehsan et al., 2016).

2.3 Seedlings Transplantation and Experiment Duration

Healthy seedlings, having the same height, were transplanted in each pot. After transplantation, small quantity of water was applied to each pot for irrigation. The *Vinca rosea* were grown on contaminated soils till flowering (42 days). All the plants were harvested and soil samples were collected from all the pots after experiment.

2.4 Experimental Variables

The uptake and removal of chromium from soil was measured by measuring of different variables as described. The height of plants was measured for each treatment of chromium to analyze the physical growth parameters.

Plant fresh weight was measured after washing thoroughly firstly with tap water and then distilled water to remove soil and other dirt particles. These plants were then first air dried and then oven dried at 120^0C overnight to remove all the moisture and dry weight was measured by electric balance. Concentration of chromium in plants and soil samples were analyzed using Atomic Absorption Spectrophotometer (AAS).

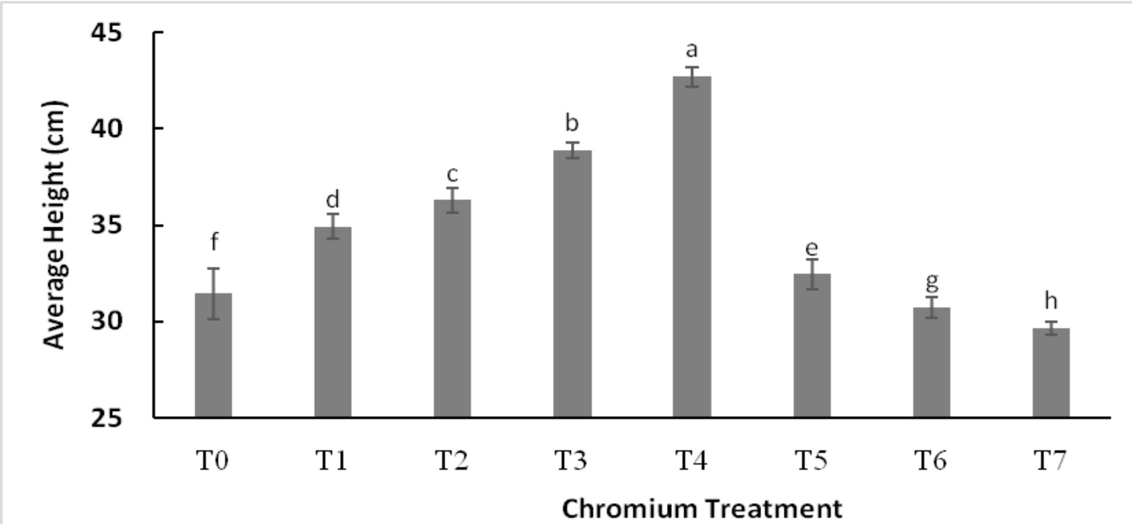

Fig. 1. Average Height (cm) of chromium Treated *Vinca rosea*

2.5 Translocation Factor

Translocation factor (TF) is the key criteria for the evaluation and selection of plants for phytoremediation purposes (Wu et al., 2011). TF is the ratio of how much the plant body has translocated the heavy metals in its vegetative part (leaves, shoot and flowers) from the roots.

For chromium concentrations in *Vinca rosea* TF was calculated using the following equation.

$$TF = \frac{\text{Conc. of heavy metal in shoot (mg/kg)}}{\text{Conc. of heavy metal in root (mg/kg)}}$$

3. Results and Discussion

After transplantation the *V. rosea* seedlings were monitored regularly for the physical parameters like plant biomass, color and growth rate of plants, flowering rate and other factors. The observations indicated that the plants with chromium levels of contamination were much healthier and the flowering rate was higher as compared to lead concentrations. It was also observed that the flowering rate decreased with increase in heavy metals levels of contamination.

3.1 Height of Plants in Contaminated Soils

Height of *Vinca rosea* in seven levels of chromium (10, 20, 30, 40, 50, 60 and 70 ppm) was measured. The plant height in control plants was 32.4 cm. A research by Shivhara and Sharma (2012) showed that the height of plants decreased as the heavy metal concentration increased.

The maximum height was observed in T_4 i.e. 43 cm, the plants with higher levels of treat i.e. (50, 60 and 70 ppm) the plants showed stunned growth and height decreased.

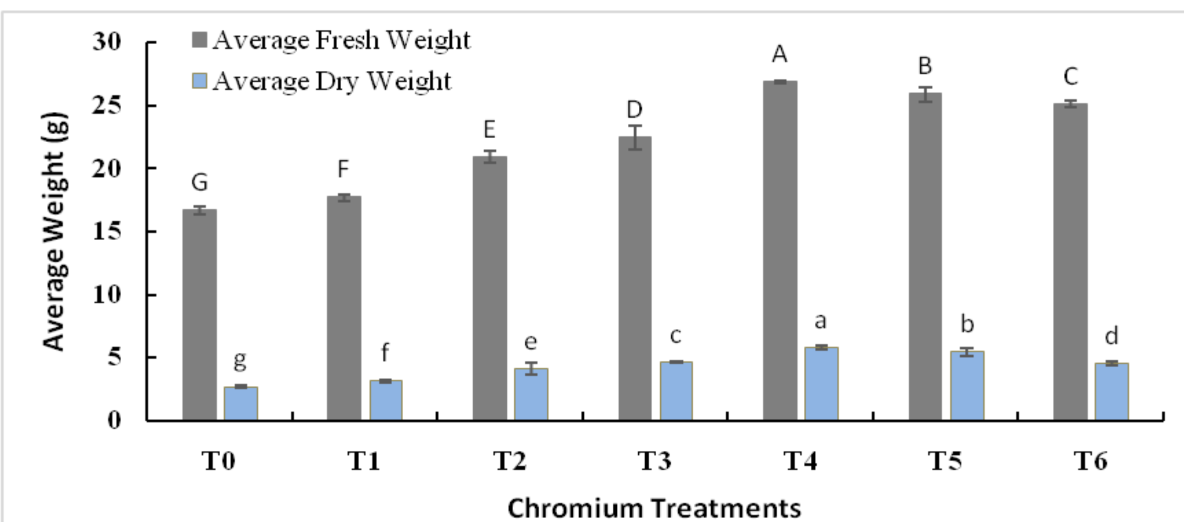

Fig 2: Average fresh and dry weight of chromium Treated *Vinca rosea*

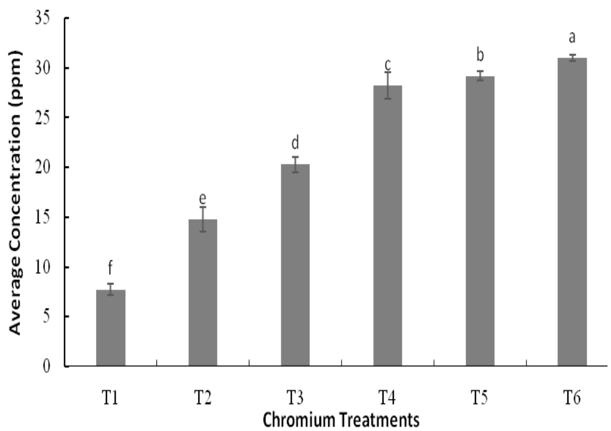

Fig. 3. Average Concentration uptake of chromium treated *Vinca rosea*

The findings of Cui et al. (2006) favors the results as it is noteworthy from the results that the lower concentration plants were lush green, and quite healthier as compared to the concentrated plant and with increase in concentration the height of plants decreased (Cui, et al 2006).

3.2 Fresh and Dry Weight of Plants in Contaminated Soils

The fresh weight in chromium contaminated *V. rosea* at T_0 (control plants) was about 17.23 g which increased with increase in T_1 (10 ppm), T_2 (20 ppm), T_3 (30 ppm) and T_4 (40 ppm). In concentrations above T4, the fresh weight of Zinnia elegance decreased. The results indicated that after few days of experimentation the plants with Chromium contamination in soil higher than 60 ppm (i.e. 70 ppm) started to wither and died within 10 days, whereas, a research conducted by Maqsood (2011) on rice plants grown in pots indicated that roots were more sensitive to chromium. The greater concentrations of chromium proved more lethal than that of lower Cr levels. The overall adverse effect of Cr on growth and development of plants may result in a serious impairment of uptake of mineral nutrients and water leading to deficiency in the shoot (Sharma and Mehrotra, 1993).

3.3 Concentration of chromium in Vinca rosea

The uptake of Chromium in plant biomass was calculated in each organ of the plants. The plant species which accumulate very high concentrations of metals in their body parts aboveground are known as hyperaccumulators. The concentration chromium in *Vinca rosea* increased with increase in concentration of chromium in soil. The Fig. 4 shows average concentration of heavy metals in plants.

3.4 Translocation Factor (TF)

The translocation factor measures the rate of the heavy metal transported from roots to leaves, shoot and flowers. The translocation rate of chromium in *Vinca rosea* was higher as compared to that of lead. BCF and TF are the key elements for the evaluation and selection of plants for phytoremediation purposes (Wu et al., 2011).

In chromium concentrations the translocation rate in T_1 is about 1.3. It remained constant for next concentration i.e. T_2 (20 ppm) however it increased significantly in 30 ppm concentration. Moreover, it remained higher than 1.3 and constant for 40, 50 and 60 ppm concentrations. The value of translocation factor greater than 1 indicates the translocation of the metal from root to above-ground part (Jamil et al., 2009). Yoon et al. (2006) stated that only those plant species which have both BCF and TF greater than 1 have the potential to be used for phytoextraction.

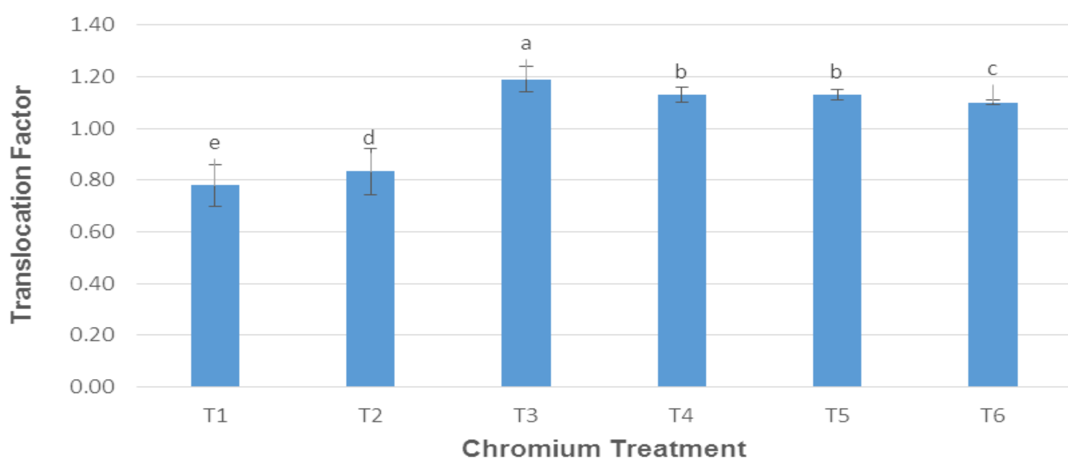

Fig 4: Average Translocation Factor of chromium Treated *Vinca rosea*.

4. Conclusion

In this study the plants grown in pots having soils with different levels of Cr treatments indicated that plant height, fresh and dry weight increased at low concentration, but decreased with high concentrations of chromium. Translocation factors was found to be lower than 1 for low level of contamination but found to be higher than 1 for higher level of contamination. Concentration of Cr in plant increased gradually from T1 to T3 and became almost constant for higher contamination levels (T4-T6). So it is concluded that *Vinca rosea* is an efficient phytoextraction species for removal of chromium naturally in arid and semi-arid soil particularly in lower concentrations.

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Competing Interests: The authors declare that there is no potential conflict of interest.

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