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Use of ornamental plant "Vinca" (*Vinca rosea L.*) for remediation of lead-contaminated soil

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Abstract

Phytoremediation potential of an ornamental plant, Vinca (*Vinca rosea*) was assessed for Lead- contaminated soil. Plants were grown in pots having soils with different levels of Pb contamination *i.e.* T1 (10 ppm), T2 (20 ppm), T3 (30 ppm), T4 (40 ppm), T5 (50 ppm), T6 (60 ppm), T7 (70 ppm), T8 (80 ppm) and T9 (90 ppm). Plants were also grown in pots with uncontaminated soil as control treatment (T0). After pot study (6 weeks), plants were harvested to measure different physical parameters and prepare plant samples for chemical analysis. Representative soil samples were collected from the pots for chemical analysis. Atomic absorption spectrophotometer (AAS) was used to measure concentration of Lead in plants and soil. The results indicated that plants were healthier and taller in lower Pb-concentration. The plant height and fresh weight decreased in higher contamination levels. The average uptake of Lead in Vinca increased with increased level of contamination. The remediation potential was higher than 1 in lower contamination level. While in higher contamination level it was low. It is concluded that Vinca plant can be used for extraction of Pb from less contaminated soil due to its aesthetic beauty and phytoremediation potential.

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Introduction

Mobilization of toxic elements such as heavy metals in soils is due to several natural and anthropogenic reasons which include application of agrochemicals, discharge of untreated industrial wastewater, use of untreated municipal wastewater for irrigation, soil acidification, etc. (Tiwaria *et al.,* 2011; Nawaz *et. al.,* 2012; Zhao *et al.,* 2012; Nawaz *et al.,* 2014). Heavy metal pollution in industries is an emerging global problem which receives least attention and control (Ogbonna *et al.,* 2015). Lead, mercury, chromium and cadmium are most important heavy metal pollutants.
In many developing countries like Pakistan this untreated wastewater is directly used for irrigation of crops (Masood *et al.,* 2012; Najam *et al.,* 2015). Yashim (2014) stated that the heavy metal contamination lead towards the ecological, nutritional and environmental toxicity. The chronic exposure of heavy metals plays a significant role in causing tumorigenesis. The exposure of lead (Pb) in blood stream affects the soft tissues and mineralizes the tissues. In children the lead exposure affects their growth metabolism, and in severe cases the central nervous system (Gonzalez *et al.,* 2008).

Phytoremediation is an effective and affordable environmental friendly technological solution used to extract or remove inactive metals and metal pollutants from contaminated soil (Hinchman *et al.,* 1995; Zhao, 2014; Aman *et al.,* 2015). The plant take advantage of selection and uptake of metals and other toxins like removal of organic and inorganic pollutants through plant roots and bioaccumulates, translocate to the above ground parts (Cho-Ruk *et al.,* 2006; Ahmadpour, 2012; Sheldrick *et al.,* 1993). Lead, cadmium, chromium arsenic and other heavy metals can be successfully removed from soil by using phytoremediation (Tangahu *et al.,* 2011).

This study aimed at assessing the phytoremediation potential of an ample ornamental plant (*Vinca rosea*) at different contamination levels of Lead (Pb).

Materials and methods

Soil preparation for pot experiment and soil characterization

Soil was collected from the normal field for conducting pot experiment. The collected soil samples were prepared for pot experiments and soil characterization by drying under shade (air dry), crushing of air dried samples by mortar and pestle, sieving of soil samples (mesh size 2 mm), and mixing thoroughly to make the samples homogeneous for experiment.

Representative sample was taken for characterization of basic properties. Soil properties were determined by different methods; Particle size distribution by hydrometer method (Hillet, 1998), Soil texture by textural triangle (Culley *et al*., 1993), Soil bulk density by core method (Culley *et al.,* 1993), soil pH by pH meter, Electronic Conductivity (EC) by EC meter (McGrath, 1987), Cation Exchange Capacity (CEC) by ammonium acetate method (Hendershot *et al.,* 1993) and soil organic carbon and organic matter by wet oxidation or walkley-black method (Nelson and Sommers, 1982).

Preparation of pots and development of contamination

The prepared soil samples were used for filling of pots. Thirty earthen pots (having 45.72 cm height and 30.48 cm diameter) were arranged for study. These pots were lined with polythene bags to avoid leaching. All pots were filled with the same calculated quantity (6 kg) of prepared soil.

The calculated amounts of lead acetate were dissolved in water to develop the required levels of contamination in pots. The prepared solutions of lead were applied to the soils in pots to develop contamination of lead. 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 heavy metals in the soil in the pots.

Plants species and experimental design

Phytoremediation study was conducted on an ornamental plant (*V. rosea*) in pots. It is a wide spread plant species, which is quite economical and grows very easily. This species is tolerant to heavy metals (like Lead). The experiment was consisted of 30 pots (1 heavy metals × 10 treatments × 3 replications).

Seedling 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. The *V. rosea* were grown on contaminated soils till flowering (42 days). All the ornamental plants were harvested. Soil was also removed from all the pots after experiment.

Experimental variables

The fresh weight was measured after washing thoroughly firstly with tap water and then distilled water to remove soil and other dirt particles. The plants were first dried in air and then oven dried at 120° C over night to remove all the moisture and dry weight was measured by the balance. The moisture content in the plants was calculated after measuring the fresh and dry weight of the plants. Concentration of heavy metals in plants and soil samples were analyzed by an Atomic Absorption Spectrophotometer (AAS). Translocation Factor (TF) is the ratio of how much the plant body has translocated the heavy metals in its vegetative part from the roots. BCF and TF are the key elements for the evaluation and selection of plants for phytoremediation purposes. Equations for calculation are as under;

$$\text{Moisture Content (\%)} = \frac{\text{fresh weight (g)} - \text{dry weight (g)}}{\text{fresh weight (g)}} \times 100$$

$$\text{BCF} = \frac{\text{conc. of heavy metal in plants (mg/kg)}}{\text{conc. of heavy metal in soil (mg/kg)}}$$

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

$$\text{Percent Removal} = \frac{\text{amount of heavy metal taken by plants (mg)}}{\text{total amount of heavy metal in soil (mg)}} \times 100$$

Results and discussion

The monitoring for the physical parameters like flowering rate, plant biomass, color and other growth factors were regularly monitored. In higher contamination levels, the flowering rate decreased and plants showed less growth for Pb-contaminated soils, as shown in Fig. 1. BCF and TF are the key elements for the evaluation and selection of plants for phytoremediation purposes (Yoon *et al.,* 2006).

Fig. 1. Experimental setup showing pots with Vinca plants at initial stage after transplantation.

Height of plants in contaminated soils

Height of *V. rosea* was measured in nine levels of lead contaminations (10, 20, 30, 40, 50, 60, 70, 80 and 90 ppm). The average plant height in the control treatment was 28 cm. It was noted that plant height increased with increase in Pb-concentration upto T5, however, in higher concentrations (T6, T7, T8 and T9) the plant height decreased. The plants were lush green, and quite healthier with lower concentrations of lead. The plants of T9 (90 ppm) showed stunted growth, very low rate of flowering. These plants died in the 3rd week after transplantation. The plant height in different treatments of Lead is shown in Fig.2. The decrease in plant height was due to increase in heavy metal concentration (Wu, 2010). The plants in lower contamination level were lush green, and quite healthier as compared to the plants grown in higher contamination level and plant height decreased with increase in concentration the heavy metals in soils.

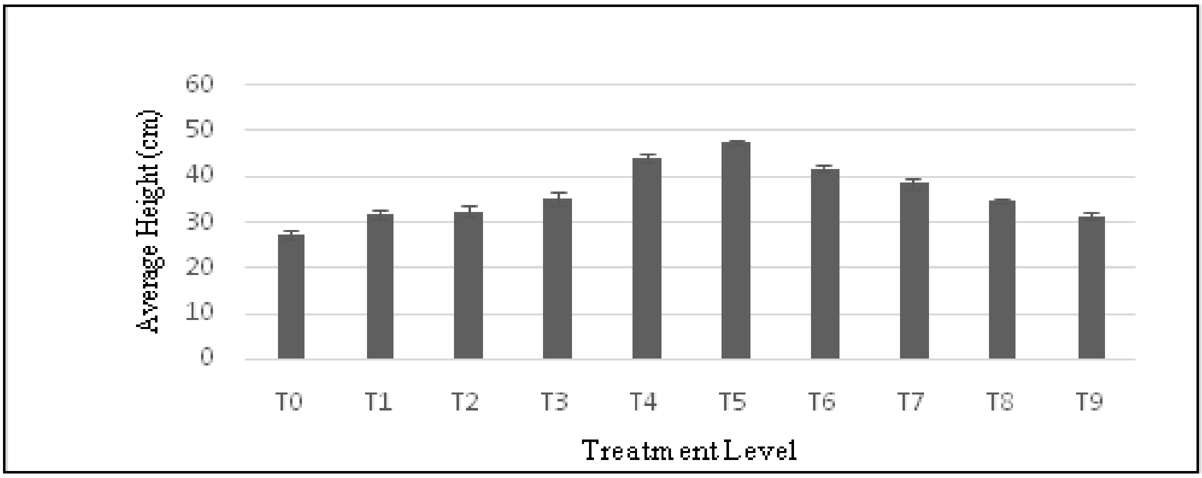

Fig. 2. Average Height (cm) of *V. rosea*.

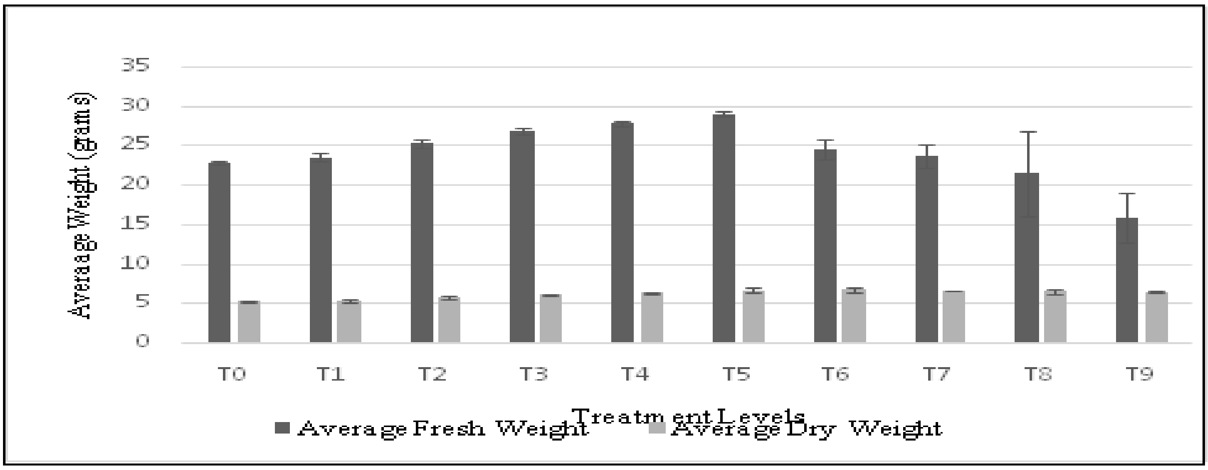

Fig. 3. Average fresh and dry weight of Lead Treated *V. rosea*.

Fresh and dry weight of plants in contaminated soils

Fig. 3 indicates that the fresh weight of plants increased with increase in contamination levels (T1, T2, T3, T4 and T5). Maximum fresh weight was observed in T5 i.e. 29 g. In higher levels of contaminations (T6, T7, T8 and T9) the fresh weight of plants dropped to about 15 g. The dry weight of Vinca in control treatments was about 4.8 g. It remained almost the same for T1, T2, and T3. In high concentrations (T4, T5, T6, T7, T8 and T9) the dry weight remained almost constant.

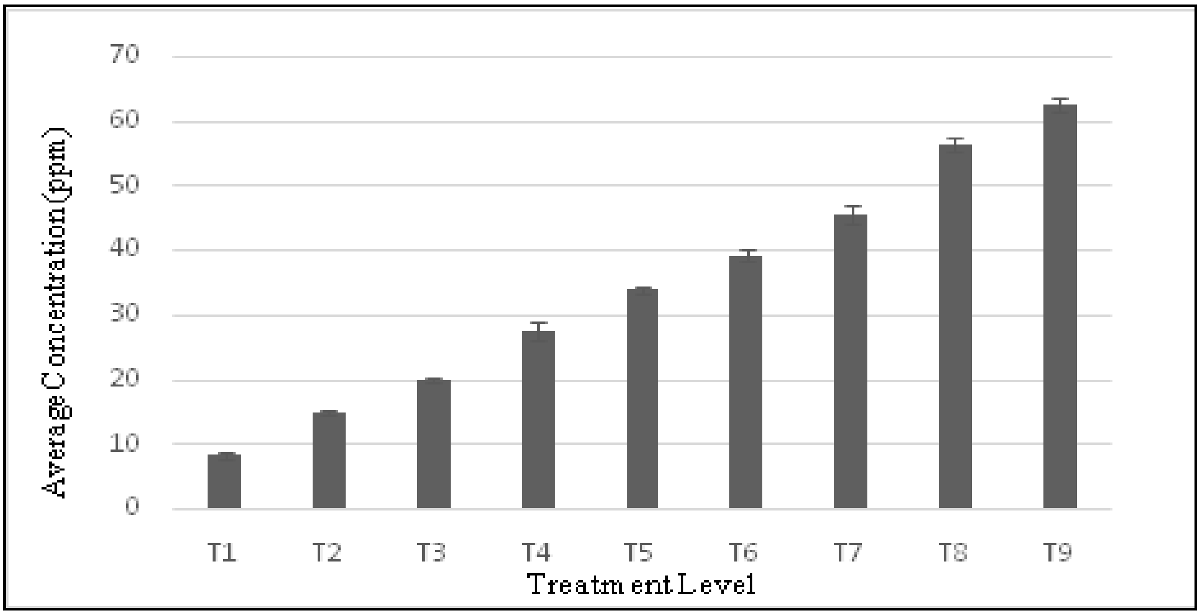

Fig. 4. Concentration of Lead in *Vinca rosea*.

Concentration of heavy metals in plants

The uptake of lead in biomass was analyzed separately in root and shoot of the plants. The plant species which accumulate very high concentrations of metals in their body parts aboveground are known as hyper accumulators. The concentration of Lead in *V. rosea* increased with increase in concentration of metal in soil. A study by Ashfaq *et al.* (2015) showed that heavy metals accumulates in above ground vegetative parts of vegetables irrigated with wastewater. Fig. 4 shows average concentration of heavy metals in plants. The results indicated that heavy metal uptake increased with increase in lead concentration in soil.

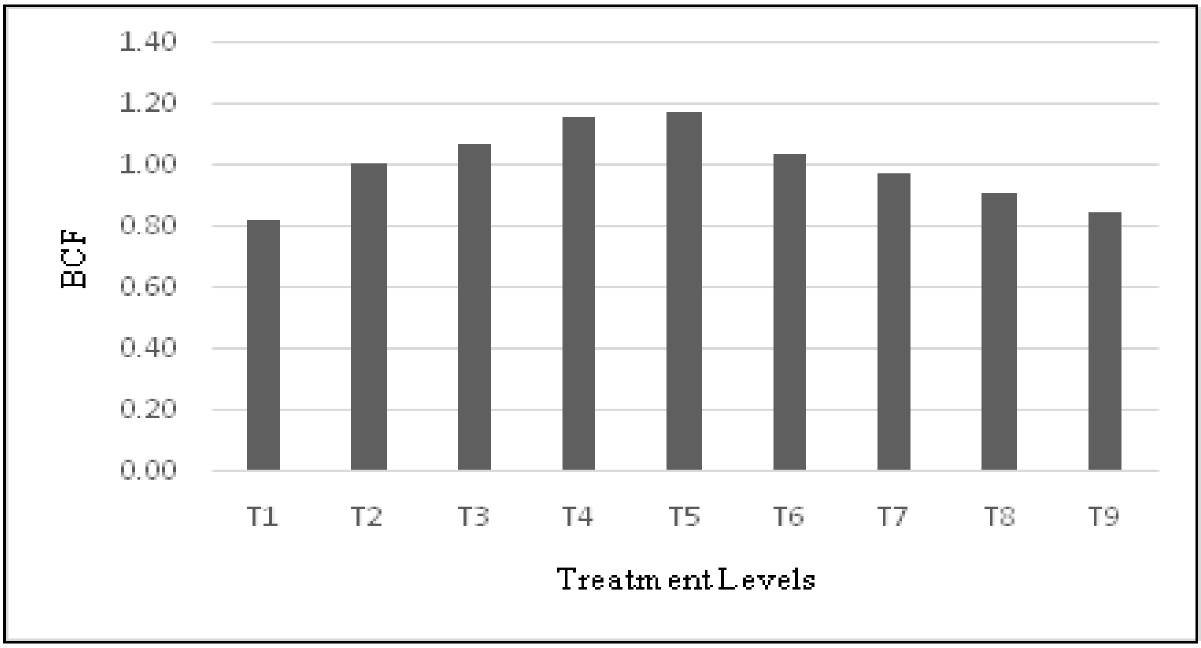

Fig. 5. Bioaccumulation Factor of Lead in *V. rosea*.

Bioconcentration factor (BCF)

The Bioconcentration Factor for Lead increased with increase in contamination level, reaching maximum in T5 (1.8). In higher contamination levels (T6, T7, T8 and T9), it decreased but remained above 0.8. The plants for which the bioconcentration factor and translocation factor is measured to be more than one (i.e. TF and BCF> 1) can be used in phytoextraction of heavy metals. Fig. 5 presents the Bioconcentration Factor (BCF) for lead in *V. rosea*. The contaminants are taken up by the roots of plants and translocated and absorbed by shoot or other above ground biomass (i.e. harvestable parts) like stem, leaves and fruits (Sekara *et al.,* 2005; Yoon *et al.,* 2006; Rafati *et al.,* 2011).

Translocation Factor (TF)

The translocation factor measures the rate of the heavy metal transported from roots to above ground parts of the plants like leaves, shoot and flowers (Mahmood, 2010). The translocation rate as illustrated in Fig. 6 shows that in T3 there was maximum translocation from soil to the above ground parts i.e.1.5. In high levels of Lead-contamination (T5, T6, T7. T8 and T9) the translocation factor decreased. Only those plant species which have both BCF and TF greater than 1 have the potential to be used for phytoextraction (Wu *et al.,* 2010). The plants with bioconcentration and translocation factors above 1 are tolerant accumulators for heavy metals and they have potential of phytoextraction. The plants with bioconcentration factor greater than one and translocation factor less than one (BCF> 1 and TF< 1) have the potential for phytostabilization (Mohmud, 2008). Therefore, Vinca can be used for phytoremediation of Pb-contaminated soils.

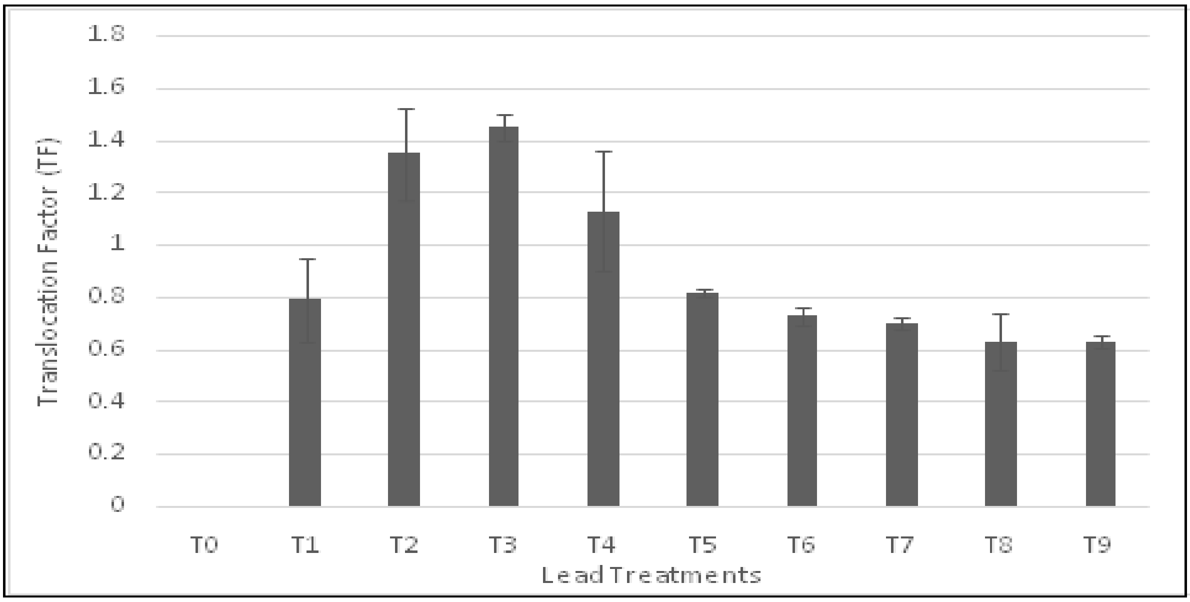

Fig. 6. Translocation Factor of Lead in *V. rosea.*

Conclusion

The phytoremediation potential of an ornamental plant, Vinca (*Vinca rosea* L.) was assessed in different levels of contaminations with lead in soil. The fresh and dry weight of Vinca was highest in 50 ppm of lead. The maximum bioaccumulation factor was 1.2. Overall, bioaccumulation factor was higher than 1 and translocation factor was less than 1 at different contamination levels. Therefore, Vinca can be used for phytoextration in lower contamination of lead and for stabilization of lead- contaminated soils in higher concentration. Using ornamental plants will remove the heavy metals from the contaminated soils in an environmental friendly way with low economic burden.

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