Phytoextraction of cadmium contaminated soils by ornamental plant: growth response, tolerance index and accumulation

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Abstract

Cadmium (Cd) contaminated soil is a global concern and restoration of contaminated soil is challenging due to its persistence and non-biodegradability. In this study the phytoextraction capability of ornamental plant (*Pelargonium zonale)* for remediating Cd contaminated soil was assessed. For this purpose, culture experiment was carried out, soil was spiked with various levels of Cd (0 – 150 mg kg^{-1}). After 1 month of spiking, pots were filled with spiked and control soils, 15 days old healthy seedlings of *P. zonale* were transplanted in all pots and grown for 2 months under greenhouse conditions, harvested and analyzed for different parameters such as Cd concentration in shoots/roots, tolerance index (Ti), Cd uptake, translocation factor (TF) and bioconcentration factor (BCF). The results showed that *P. zonale* survived at highest Cd levels and Ti was more than 60%. Furthermore, the TF and BCF was more than 1 and Cd accumulation in the shoots was more than 100 mg kg^{-1}. This study showed that *P. zonale* has great capability for restoring Cd contaminated soils.

Keywords: Cadmium, Phytoextraction, *Pelargonium zonale*, Tolerance Index

1. Introduction

The release of excessive amount of contaminants such as heavy metals (**Gul et al. 2019a,b; Manzoor et al. 2018**), antibiotics (**Mukhtar et al. 2020**) and hydrocarbons are responsible for the soil degradation. Among different contaminats, heavy metals particlualry cadmium (Cd) is of serious concern due to its non-essentiality, persistent, non-biodegradable, nature (**Dong et al. 2007; Gul et al. 2019b**). Man-made sources of Cd including but not limited to mining, phosphate fertilizers with high impurities, industrial waste and effluents, use of waste water for irrigation, fossil fuel combustion are the main contrinutors for soil contamination (**Ahmad et al. 2011**). This heavy metals has similar chemistry with the essential nutrinet i.e zinc and therefore can be taken up by plants and cause significant risk to environment and human health.

To decontaminte the soil and make it Cd free various conventional methods have been adopted. Most of the conventional techniques affect the soil physico-chemical properties and are economically not suitable (**Arshad et al. 2008**). Plants have natural ability to survive and uptake contaminants along with essential nutrinets. Due to the inherent capability of plants to uptake the coontaminats and transfer to the aerail parts they are used for the decontamination of soil and this technique is named as phytoremedtaion. The use of plants for the restoration of soil is suitable, cost effective, environment friendly and promising technique (**Gul et al. 2019c; Manzoor et al. 2020; Bhargava et al. 2012**). Dıfferent plants have been used for the phytoremediation, most of the studied plants are crops or wild plant, use of these plants increased the risk of food chain contamination. Therefore, the focus of researchers has been shifted to the use of ornamental plants. Amog different ornamental plants, the Pelargonium species were found to be efficient in the remoavl of heavy metals from soil, many of the species such as Pelargonium roseum, capitatum, peltatum, citrosum, domesticum, hortorum have been used for phytoextraction strategies (**Arshad et al. 2020, 2016; Manzoor et al. 2018; Mahdeih et al. 2013**). KrishnaRaj et al., (2000) reported that Frensham (Pelargonium specie) accumulated 4.72%, 0.17% Pb, 0.44%, 0.07% Cd, 0.52%, 0.14% Ni per kg of root and shoot, respectively within two weeks (**Krishnaraj et al. 2000**). Another study reported that *Pelargonium roseum* was exposed to the mixture of heavy metals (Ni, Cd, Pb), accumulated 20,055 mg Ni, 86,566 mg Pb, 31,267 mg Cd per kg of root dry weight, as well as 10,889 mg Ni, 4.416 mg Pb, 1,957 mg Cd per kg of shoot dry weight within two weeks (**Mahdeih et al. 2013**). The objectives of this study were: (a) to explore the phytoremediation capability of *Pelargonium zonale* in Cd contaminated soil (b) to assess the impact of Cd on the growth of *Pelargonium zonale*.

2. Materials and Methods

2.1 Culture Experiment

Pot experiment was conducted to evaluate the phytoremediation abilities of *Pelargonium zonale*. For the experimental work, soil from un-contamianted site was collected, dried and mechanically crushed by using ball mill and sieved (2mm mesh). Soil parameters including pH, electrical conductivity, texture and concentration of Cd was analyzed. The soil has 7.4 and 0.5 Ds m^{-1} pH and Ec, respetively. The Cd was not found in the collected soil. The soil was spiked in containers by using cadmium sulfate salt [$CdSO_4$] to achieved the desired doses i.e. 25 - 150 mg kg^{-1}. The pots were filled with 350 g of spiked soil and 1 month old seedlings of *Pelargonium zonale* was transplanted in each pot. The control (without Cd) was also set for comparison. Plants were exposed for 8 weeks under natural conditions.

2.2 Harvesting, growth response and Cd Analysis

Plants were carefully removed from all pots, rinsed with distilled water and for the remoavl of exteranl Cd plants were immersed in 0.01M HCl solution and again rinsed with distilled water. Plant was carefully separated in roots and shoots. The growth parameters such as fresh biomass was measured, afterwards plants were dried at 70 ºC in oven until complete dryness for dry biomass (**Gul et al. 2019a**). For the analysis of Cd plant samples were grinded to make powder and digestion with nitric acid and perchloric acid at a ratio of 3:1 on hot plate. Cadmium contnet in digested samples were analyzed by using atomic absorption spectrophotometer (**Manzoor et al. 2018**).

2.3 phytoremediation ability parameters and tolerance index

The bioconcentration factor (BCF) and translocation factor (TF) was used for the determination of *Pelargonium zonale* capability for Cd phytoremediation.

BCF = [Cd in roots / Cd in soil]

TF = [Cd in shoots / Cd in roots]

The tolerance index (Ti) measured the ability of plants to grow in the presences of given concentration of Cd. Ti was calculates as:

$Ti = [(DW)_{\text{treated plant}} / (DW)_{\text{control plant}} x\ 100]$

Total Cd uptake was also calculated with the help of following equation.

Cd uptake = [(shoot DW x Shoot Cd conc.) + (root DW x root Cd conc.)]

2.4 Statistical Analysis

Data presented is the mean of three replicate. For significant difference ($P<0.05$) ANOVA was applied using Statistix software 8.0.

3. Results and Discussion

3.1 Cd in plant organs

Figure 1 indicates the Cd concentration in roots and shoots of *Pelargonium zonale*. The trend of Cd accumulation in roots and shoots of *Pelargonium zonale* increased as the concentration of Cd supply increased. The highest concentration of Cd in root and shoot of *Pelargonium zonale* was 80.23 and 186 mg kg^{-1} respectively at higher Cd treatment. *Pelargonium roseum* has been reported as hyperaccumulator as it accumulates more than 100 mg kg^{-1} of Cd in shoot when compared with control group (**Mahdieh et al. 2013**). Another study showed that attar of rose, clorinda and atomic snowflake accumulates 1.4-, 1.2- and 1.1- folds more Pb in shoots than the threshold value for the Pb hyperaccumulator plant (**Arshad et al. 2008**).

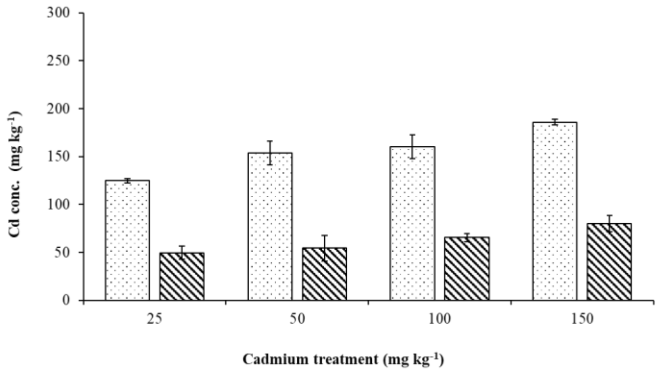

Figure 1. Cd concentration in root and shoot of plant species

3.2 Phytoremediation ability and Cd uptake

Table 2. indicates that translocation factor of *Pelargonium zonale* was greater than 1, which indicates that *Pelargonium zonale* have ability to transloacte Cd in the aerial parts of the plants. The BCF was greater than 1 at the lower Cd levels i.e. 25 and 50 mg Cd kg^{-1}, however, the BCF was lower than 1 at higher Cd levels. The possible reason for the lower BCF at higher Cd level is that plant might be unable to survive at higher level as it is also indicated by the Ti that at higher Cd level the Ti was reduced.

Table 2. Translocation and bioconcentration factor of *Pelargonium zonale*

Treatment (mg kg^{-1})	TF	BCF
25	2.52	1.98
50	2.82	1.1
100	2.45	0.65
150	2.32	0.53

Figure 2 shows the Cd uptake per plant of *Pelargonium zonale*. The maximum Cd uptake by *Pelargonium zonale* was 0.014 mg. With increasing Cd supply the uptake also increased, it has been observed that at higher Cd level the biomass reduced (data not presented) but the Cd concentration in plant increased therefore, the Cd uptake per plant increased.

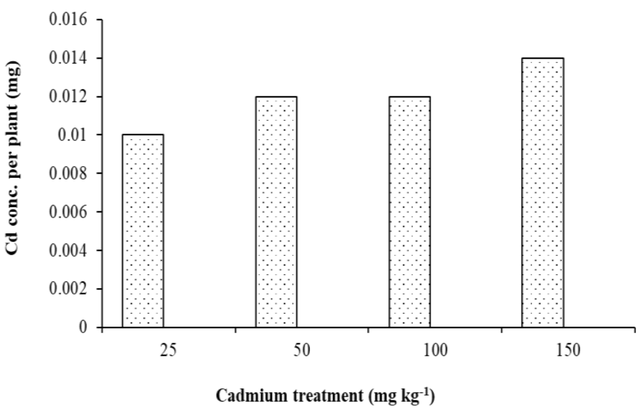

Figure 2. Cd uptake by *Pelargonium zonale*

3.3 Tolerance index

Figure 3 indicates the tolerance index of *Pelargonium zonale* after eight weeks treatment with Cd. As the concentration of Cd increased, the Ti of *Pelargonium zonale* decreased. At the highest treatment level of *Pelargonium zonale*, has good tolerance towards Cd, as the Ti value was more than 60%. Syuhaida et al., (2014) reported that Ti of water mimosa and water hyacinth after treatment with Pb, Cu and Cd decreased as the heavy metals concentration increase. The Ti to Cd for water hyacinth reduced from 91 % to 37% treated.

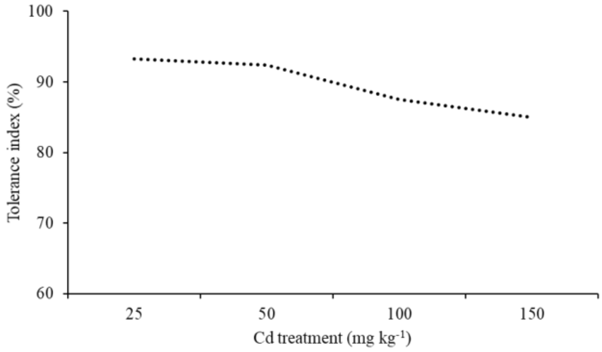

Figure 3. Tolerance index of *Pelargonium zonale* in Cd

4. Conclusions

The soil contaminated with Cd may be remediated by using hyper accumulator plants. The study evidence that *Pelargonium zonale* have ability to accumulated Cd in the aerial parts of the plant. *Pelargonium zonale* have translocation factor >1, and accumulate more than 100 mg kg^{-1} of Cd and considered as hyper accumulator. Therefore, *Pelargonium zonale* has great potential to remediate Cd contaminated soil.

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