

RESEARCH PAPER

Phytoremediation Efficiency of Some Evergreen Plant Genera for Lead Polluted Soil

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ABSTRACT:

A pot experiment was performed to determine the efficiency of phytoremediation of some evergreen plants to lead in a polluted soil. The experiment was a factorial completely randomized design with three replications. The first factor was four evergreen plant genera involved *Dodonaea viscosa* L., *Myrtus communis* L., *Platycladus orientalis* L. and *Ficus benjamina* L. used as phytoremediators. Whereas, the second factor was different concentrations of lead (0, 100, 200 and 300 mg.kg⁻¹) which were prepared using laboratory grade PbCl₂. The results indicated that the highest bioaccumulation factor (BF) (39.15 and 19.39) were observed in *Dodonaea viscosa* and *Ficus benjamina* respectively. However, the maximum values of total Pb (127.53, 1084.96 and 106.99 mg.kg⁻¹) were detected in *Platycladus orientalis*, *Dodonaea viscosa* and *Myrtus communis* respectively. The values of BF and translocation factor (TF) showed that *Dodonaea viscosa* is the most effective phytoremediator among the other studied plants.

KEY WORDS: Lead, Phytoremediation, Soil, Pollution.

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1. INTRODUCTION

Recently, the type and content of heavy metals have gradually increased due to human activities, resulting in environmental deterioration. Heavy metals can enrich through food chains, thus they are highly hazardous to the environment and organisms (Jean-Philippe *et al.*, 2012; Sayadi and Rezaei, 2014). The most contaminant heavy metals are arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), mercury (Hg) and nickel (Ni). Pb and Cd gained more attention because they are widely spread, highly toxic to plant functions (Verma and Dubey, 2003) and more persistence, so they cannot degrade naturally like other organic pollutants and they accumulate in different parts of food chains (Khudhur, *et al.*, 2016).

Many studies showed that lead is one of the inhibitors of plant metabolic processes such as water uptake, nitrogen assimilation, respiration, photosynthesis and transcription. Lead may inactivate various enzymatic activities via binding to sulfhydryl (SH-) groups and intensifying reactive oxygen species (ROS) production leading to oxidative stress (Prasad *et al.*, 1999). Moreover, lead can negatively affect the structure of mitochondria through decreasing mitochondrial cristae and in turn lowering the capability of oxidative phosphorylation (Malecka *et al.*, 2001).

Soils may be polluted with heavy metals due to their potential toxicity and high persistence, and represent serious environmental problems that require effective and reasonable solutions. Thus, phytoremediation, a remediation method of contaminated soils, has developed with more cost-effective and fewer side effects than chemical and physical approaches (Lone *et al.*, 2008). Phytoremediation is a diverse plant-based technologies used for cleaning contaminated soils by applying either naturally occurring or

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genetically engineered plants (Flathman and Lanza, 1998).

There are several phytoremediation mechanisms like phytostabilization, phytovolatilization or phytoextraction of the heavy metals from plant harvesting sites. Phytoextraction is the most promising technique that has received increasing attention from researchers for remediating heavy metal polluted soils (Robinson *et al.*, 2009). Plant species that accumulate high concentrations of heavy metals in their shoots and produce large biomass after removing a great amount of metal should select for phytoremediation (Lone *et al.*, 2008). The rapid increases in population growth and industrial development in Kurdistan region of Iraq in the last fifteen years have resulted in increasing the demand of energy, specific translocation vehicles and building raw materials. For these purposes a large amount of several heavy metals particularly lead from various sources were discharged to the environment without any quality control, monitoring and prehistoric analyses, thus this study aimed to assess the phytoremediation efficiency of some evergreen plant genera to lead in polluted soil.

2. MATERIALS AND METHODS

2.1. Experimental design

A pot experiment was carried out to evaluate the phytoremediation efficiency of some genera of the evergreen plant to Pb in a polluted soil; the experiment was a factorial completely randomized design with three replications. The first factor was four evergreen plant genera, which involved *Dodonaea viscosa* L., *Myrtus communis* L., *Platycladus orientalis* L. and *Ficus benjamina* L. used as phytoremediators. Whereas, the second factor was different concentrations of lead (0, 100, 200 and 300 mg.kg⁻¹) which prepared by using laboratory-grade PbCl₂. Forty-eight experimental pots under sixteen combined treatments were tested each with three replications. Each pot packed with 16 Kg air-dried soil, after sieving via 4-mm sieve. Some physicochemical characteristics of the studied soil (table 1) were determined according to the described methods by (Richards,1954; Allen *et al.*,1974; Ryan *et al.*, 2001 and Pansu and Gautheyrou, 2006). Three plants of each genera were planted in each pot.

Plants were irrigated with water whenever needed to maintain soil moisture near field capacity by weighting methods and weeding done were needed.

Table 1: Physical and chemical characteristics of the studied soil.

Soil properties		Values
Particle size distribution (%)	Sand	63.0
	Silt	13.2
	Clay	23.8
Texture name		Sandy Clay Loam
Moisture content (%)		4.50
pH		7.56
Electrical conductivity (EC) (dS.m ⁻¹)		0.40
Organic Matter (OM) (%)		0.61
Total nitrogen (N) (%)		0.11
Total phosphorus (P) (ppm)		23

2.2. Sampling and analyses of soil and plants

Soil samples were collected using core sampler (23 cm high and 4 cm in diameter) from the base of each uprooted plants, and packed in properly labeled polyethylene bags. Samples were oven-dried at 105°C for 24 hours then sieved and kept in small containers until analyses. Plants were harvested six months after growth, each plant genera were separately collected and packed in properly labeled polyethylene bags. Plant samples were washed and cleaned with tap water, then oven dried at 70°C for 24 hours, and ground into a powder and kept in small containers until analyses. Wet and dry weights of shoot and root systems were taken. Lead concentration in the soils and plant parts were determined using the XRF device (Genius 5000 XRF) (Khudhur, 2018).

2.3. Pollution quantification

The quantification of soil pollution was calculated through transfer factor (TF), plant bioaccumulation factor (BF), contamination factor (CF) and pollution load index (PLI).

2.3.1. Bioaccumulation factor (BF)

Bioaccumulation factor is the ratio of contaminant from the plant's root and shoot to soil, and used as a measure of plant effectiveness in concentrating pollutants into aerial part (Fayiga *et al.*, 2004).

The following formula is used for calculation of bioaccumulation factor (BFs):

$$BF = \frac{M_{shoot}}{M_{soil}} \dots\dots\dots (1)$$

Where: M_{shoot} is the metal content in shoot (mg.kg⁻¹ dry wt); M_{soil} is the total metal content in soil (mg.kg⁻¹). M_{soil} was determined by adding natural total soil content of metal with its applied content in soil.

2.3.2. Translocation factor (TF)

Translocation factor is used to calculate the efficiency of a plant in transferring a chemical from roots to shoots. It is the quotient of contaminant concentration in shoots to roots (Sun *et al.* 2011). Translocation factor (TFs) calculates by this formula:

$$TF = \frac{M_{shoot}}{M_{root}} \dots\dots\dots (2)$$

Where: M_{shoot} is the metal content in shoots (mg.kg⁻¹ dry wt); M_{root} is the metal concentration in roots of the plants (mg.kg⁻¹ dry wt).

2.3.3. The Contamination Factor (CF)

To assess the concentration of a metal, a normalization method has suggested by Simex and Helz (1981). By this study, CF normalized lead concentrations using Al and its background concentration was normalized in unaffected soil from the studied area (Khudhur *et al.*, 2018). EF is calculated as follow:

$$CF = \frac{M_{sample}}{M_{background}} \dots\dots\dots (3)$$

2.3.4. Pollution Load Index (PLI)

PLI has calculated as nth root of the product of the n CF, according to the equation adopted from (Muhammad *et al.*, 2013).

$$PLI = (CF_1 \times CF_2 \times CF_3 \times \dots \times CF_n)^{1/n} \dots\dots\dots (4)$$

2.4. Statistical Analyses

The experimental layout was a factorial completely randomized design (Factorial CRD). Data were statistically analyzed using SPSS version 23. All data expressed as mean value, the

difference among the means of plant genera, lead concentration and their combination were compared by applying Duncan multiple comparison tests at the level of significant 5% (Townend, 2002).

3. RESULTS AND DISCUSSION

From the analysed data given in (table 2), the plant genera were significantly (p ≤ 0.05) affected by the total concentration of lead in shoot, root and soil.

Table 2. Concentration of lead in shoot, root and soil of various plant genera.

Plant genera	Lead concentrations mg.kg ⁻¹		
	Shoot	Root	Soil
<i>Dodonaea viscosa</i>	70.42 ^b	1084.96 ^a	96.77 ^a
<i>Myrtus communis</i>	69.75 ^b	326.69 ^a	106.9 ^{9a}
<i>Ficus benjamina</i>	27.08 ^c	541.35 ^a	55.08 ^a
<i>Platycladus orientalis</i>	127.53 ^a	592.29 ^a	64.95 ^a

The maximum Pb values of 127.53, 1084.96 and 106.99 mg.kg⁻¹ were recorded by *Platycladus orientalis*, *Dodonaea viscosa* and *Myrtus communis* respectively. The variation of Pb content in various plant genera is highly related to environmental factors in addition to variation in physiological and anatomical properties of roots. The results indicate that the higher concentration of pb recorded in the root system of all plants, and this may be related to the limited transfer of lead in plant, thus a great proportion is accumulated by roots and this result and interpretation agreed with those reported by (Kabata-Pendias and Pendias, 2001).

The data presented in (table 3) revealed that the application of different levels of lead significantly (p ≤ 0.05) were affected the total concentration of lead in shoot, root and soil.

Table 3. Effect of different Pb doses on lead concentration in shoot, root and soil of various plant genera.

Pb Doses mg.kg ⁻¹	Lead concentrations mg.kg ⁻¹		
	Shoot	Root	Soil
D0(control)	50.39 ^a	35.96 ^b	11.01 ^b
D1(100)	64.17 ^a	215.19 ^b	66.16 ^b
D2(200)	90.72 ^a	860.37 ^{ab}	87.01 ^{ab}
D3(300)	89.49 ^a	1433.77 ^a	159.61 ^a

The highest value (90.72) and (1433.77, 159.61) mg.kg⁻¹ were recorded in treatments that received (200) and (300) mg lead.kg⁻¹ respectively. This may be due to the accumulation

of lead near the soil surface and mainly due to its sorption by clay mineral fraction particularly calcite, thus the availability of lead in this kind of soil decreased. The results indicate that the concentration of lead in shoot, root and soil increase with increasing the applied doses, and the reason behind the higher concentration of pb in root and shoot systems is that the absorption of Pb is passive thus the rate of its uptake from the soil is higher. This result and explanation are similar to those reported by (Kabata-Pendias and Pendias, 2001).

The application of Pb to soil significantly affects the plants BF and TF values (figure 1). According to the results, TF for all plant genera is < 1.

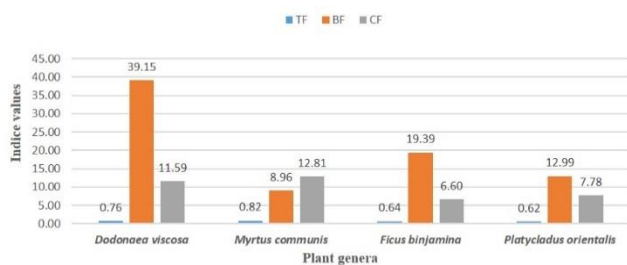


Figure 1. Transfer Factor, Bioaccumulation Factor and Contamination Factor of Pb in plant genera

This indicates the effective translocation of Pb from roots to shoot had the lowest TF. This demonstrates a lower ability to translocate Pb from the root to aboveground biomass and indicates the capability of these plants for absorbing and accumulating Pb in their roots. The highest BF values (39.15 and 19.39) were observed in *Dodonaea viscosa* and *Ficus benjamina* respectively, while the lowest BF values (12.99 and 8.96) were determined in *Platycladus orientalis* and *Myrtus communis* respectively. Although, these plants had high values of BF, they have the lowest TF in contrast. As well as, the CF in *Myrtus communis* and *Dodonaea viscosa* had the highest values with (12.81 and 11.59) respectively, and *Platycladus orientalis* and *Ficus benjamina* had the lowest value with (7.78 and 6.60) respectively.

The analysed data in (figure 2) showed that the value of BF and CF were increased with increasing the applied dose of lead. The maximum values (34.89 and 19.12) were observed in treatment that received 300 mg.kg⁻¹ of lead, while the result indicates that the value of TF decreased with increasing the lead doses. According to the

values of BF and TF, *Dodonaea viscosa* was the most effective phytoremediator among all plant genera, and these results are similar to those reported by (Celebi *et al.*, 2017). However, pollution load index (PLI) of Pb concentrations was 4.95, which reveals high Pb contamination in soil (Muhammad *et al.*, 2013).

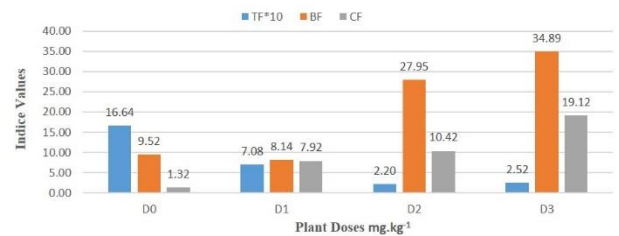


Figure 2. Effect of different levels of Pb on Transfer Factor, Bioaccumulation Factor and Contamination Factor.

These results and interpretations were confirmed by recording a significant positive correlation between Pb doses and its concentrations in shoot and root system of the plants with correlation coefficient $R^2 = 0.939$ and 0.978 respectively. (Figures 3 and 4). Similar results reported by (Muhammad *et al.*, 2013).

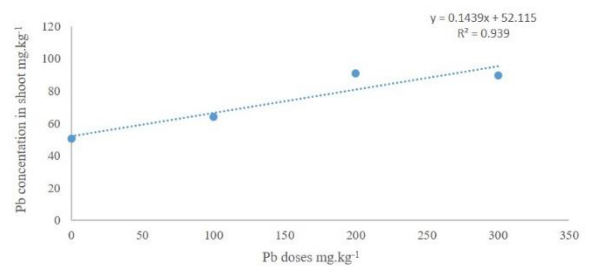


Figure 3. Correlationship between Pb doses and lead concentration in shoot system

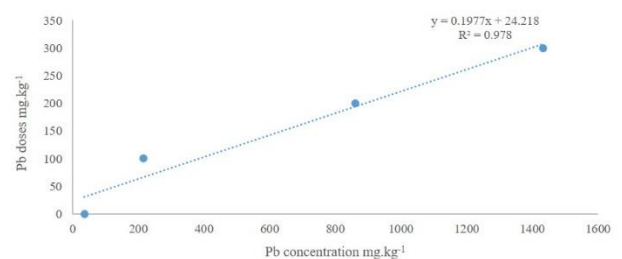


Figure 4. Correlationship between Pb doses and Pb concentration in root system

4. Conclusion

By the present study, although, the soil was highly polluted by lead according to pollution load index value ($4.95 > 1$), *Dodonaea viscosa* showed the strongest tendency toward absorption and accumulation of lead in its tissues among the other

selected plants. This may be due to the root type of *D. viscosa*, which is fibrous and has a large surface area to cover and absorb more soil metals. By increasing Pb doses, a gradual increase of Pb concentrations is revealed in shoot and root systems, which suggests the plant efficiency to accumulate more heavy metals by time without damaging and affecting any of its tissues.

Conflict of Interest

The authors have no Conflict of Interest.

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