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The comparisons between *Picea abies* and *Pinus sylvestris* in respect of lead phytoremediation potential

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Abstract

Nowadays, heavy metal`s pollution has made some environmental problems in the biosphere. The technique of phytoremediation is using the plants in removing these environmental pollutants .In this study, Forty five three-year old seedlings of *Pinus sylvestris L* and *Picea abies (L.) Karst* were planted in plastic pots that there were put in open area. For each species, fifteen pots were treated with three lead concentrations 0 (control), 800, and 1600 mg Kg^{-1}. At the end of October the amounts of Pb in roots, stems, leaves and soil were measured using ICP. Random data in 15 repetitions were analyzed using one-way analysis of variance. The results indicated that unlike *Picea abies*, *P. sylvestris* was suitable as a lead phytoremediation plant. In 800 mg kg^{-1} the Pb accumulation in both parts of *P. sylvestris* roots and stems while in high concentration 1600 mg kg^{-1}, maximum Pb accumulation was observed in roots and leaves. In the species *Picea abies* we didn't observe any significant differences in Pb absorption between treatment and control up to 800 ppm, while in 1600 ppm Pb concentration was transported to stems and leaves. Comparison between the remaining Pb in different treatment levels of each horizontal layer of soil in *P.sylvestris* seedlings showed there was a significant difference only in first layer of soil. In *P.abies* there were significantly differences in horizons first and third. In conclusion, *Pinus sylvestris* is more suitable for Pb phytoremediation than *Picea abies*.

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Introduction

Environmental pollution is a matter of great concern and has been accepted as global problem because of its adverse effects on human health, animals and plants. Soil ecosystem through the world has been contaminated with heavy metals by various human activities (Iqbal *et al.*, 2011).

Most of the conventional remedial technologies are expensive and inhibit the soil fertility; this subsequently causes negative impacts on the ecosystem. Phytoremediation is a cost-effective, environmental-friendly, and aesthetically-pleasing approach, most suitable for developing countries (Ghosh & Singh, 2005).

Bioremediation, *i.e.* the use of living organisms to manage or remediate polluted soils, is an emerging technology. It is defined as the elimination, attenuation or transformation of polluting or contaminating substances by the use of biological processes (Pal *et al* 2010).

Heavy metals are the components of the earth crust. They cannot be degraded or destroyed. Metals like zinc, iron, copper, chromium, and cobalt are essential nutrients, but become toxic at high concentrations. Lead and cadmium have no known beneficial properties and thus are exclusively toxic (Beket & Davis, 1988, Iqbal *et al.*, 2011).

Lead is the most common of the heavy elements. Several stable isotopes exist in nature, Pb being the most abundant (Michael *et al.*, 2007; Perveen *et al.*, 2011). The contamination of soil and water with lead (Pb) mostly results from human activities. Various industries, such as mining and smelting, the past and present use of lead in paints, gasoline, and linings have resulted in its spreading all over the world. Lead is extremely toxic to all intermediates of food chains (Wierzbicka *et al.*, 1993; Henry, 2000; Piechalak *et al.*, 2002; Brunet *et al.*, 2008). Lead accumulates in the body organs (i.e., brain), which may lead to poisoning or even death. The gastrointestinal tract, kidneys, and central nervous system are also affected by the presence of lead (Perveen *et al.*, 2011). Lead is indeed easily found in nature in oxidized forms (oxides and salts) that have been used for metal extractions almost since the beginning of civilization. In soil lead often exists as a divalent cation, Pb^{2+}, which is prone to the cation exchange and sorption/solubility phenomena associated with most soils. Therefore, the activity of free Pb^{2+} in soils varies, and is dependent on the solubility of the controlling lead phase (Elless & Blaylock, 2000, Hassan *et al.*, 2008).

The potential use of trees as a suitable vegetation cover for heavy metal-contaminated land has received increasing attention over the past 20 years (Aronsson and Perttu, 1994;Glimerveen, 1996; EPA, 1999 & 2000; Pulford and, Watson, 2003) Trees have been suggested as a low-cost, sustainable and ecologically sound solution to the remediation of heavy metal-contaminated land (Dickinson, 2000; Pulford and, Watson, 2003), especially when it is uneconomic to use other treatments or there is no time pressure on the reuse of the land (Riddell-Black, 1994; Pulford and, Watson, 2003).Scientists are investigating phytoremediation's potential by using plants such as willow (Punshon and Dickinson ,1997; Watson, 2002), oats(Astolfi *et al.*, 2004) wheat (Iqbal *et al.*, 2011) . Some woody species can be advantageously used also for phytoremediation of soils and groundwater from organic pollutants and hydrocarbons. Many studies have thus been focused on the use of willows and poplars in phytoextraction (Capuana M,2011).Perveen *et al.*, (2011) studied Pb phytoremediation potential in *Jasminum saambac* and showed this plant accumulated Pb in root, leaf, and stem.

Pinus sylvestris L. is an evergreen coniferous tree growing to 25–40 meters in height when mature. *Picea abies* (L.) Karst. is a large, fast-growing evergreen coniferous tree growing to 35-55 m tall. There are used in forestry and as an ornamental tree in parks and gardens. Both of trees are widely planted in parks and along streets or highways in urban sites.

In this study, work was undertaken with following objectives:

i) To assess the Pb phytoremediation potential of *Pinus sylvestris* and *Picea abies* three-year old seedlings that use as an ornamental tree urban.

ii) To determine the concentration of remediated Pb in different parts of *Pinus sylvestris and Picea abies* root, stem and leaves.

Materials and methods

Plant growth conditions

Forty five three-year old seedlings of *Pinus sylvestris* and *Picea abies* were planted in plastic pots with sand-loam-clay soil, at the end of March, 2011. The soil physico-chemical properties have been given in Table1.

Table 1. Physico-chemical properties of pots soil before treatments.

AMOUNG	CARACTERS
40%	Sand
40%	Silt
20%	Clay
1.7	EC
7	pH
22.44 mg kg^{-1} soil	Pb amount

Pots were put in open area and protected by plastic roof to remove rain effects. The plants were allowed to grow for two months, watered with tap three times a week during that time. After this time, a solution of lead nitrate ($Pb(NO3)2$),was prepared in two concentrations of 800 and 1600 mg kg^{-1}. For each species, fifteen pots were treated with three lead concentrations 0 (control), 800, and 1600 mg Kg^{-1}. We added 30 ml of each concentration to the pots two times at the end of June.

Plant analysis

At the end of October samples were obtained from different organs including root, stem, leaf and soil of pots. Leaf samples were taken from all directions of crown. The small parts of the stem and root including upper, center and lower regions were collected as one sample. Soil samples were gathered from different depths including 0-5, 5-10, 10-20 cm of soil surface. Plants samples were washed with tap water and dried to remove any possible pollution. After harvest, fresh weight of samples was determined, whereas its dry weight was measured after ventilation at 75 C° for 48 hours.0.25gr of dried and powdered samples was extracted using 4 ml sulfuric acid (98%) and 13 ml hydrogen peroxide (30%) as prescribed by Pichtel and Bradway (2008). Pb concentration was determined in each filtered extracts using ICP, GBC (Australia). (Youngsoo Cho *et al.*, 2009).

Data Analysis

Statistical analyses were done using one-way variance in completely random block in 15 repetitions. Mean comparison was done by Duncan and James Havel test using SPSS software.

Results and discussion

The comparison between root, stem and leaf of *P. sylvestris* regarding Pb concentration demonstrated that root and stem have high amount of Pb rather than leaf in 800 mg kg^{-1} treatment. In 1600 mg kg^{-1} the concentration of Pb showed different ranges in root, stem and leaf. This amount in root was more than what seen in stem and leaf. Among them leaf had the lowest Pb concentration. (Fig.1A). However, there were no significant differences in Pb concentration through root, stem and leaf of *P. abies* in any of treatment (Fig1B).This results showed that Pb has been transferred easily in *P. sylvestris*. This issue indicates the differences between two species regarding physiological mechanisms in Pb absorbance. *Pinus sylvestris* has more potential to use in Pb phytoremediation.

The Pb uptake in *P. sylvestris* in two different concentrations 800 and 1600 mg kg^{-1} was more than the control (Fig. 2A) but in *p. abies* no significant differences were seen through roots under the treatment and control (Fig. 2B). In the stem of *P.sylvestris*, this difference was observed between the seedlings treated by 800 mg kg^{-1} of Pb and those which received 1600 and 0 mg kg^{-1} of lead nitrate (Fig. 2A), in the stem of *P.abies* higher Pb accumulation was seen in 1600 mg kg^{-1} treatment rather than the control significantly (Fig. 2B). The highest amount of Pb was observed in the leaves of *P.sylvestris* and *p.abies* seedlings treated by 1600 mg kg^{-1} Pb(No3)$_2$ (Fig. 2A&B).

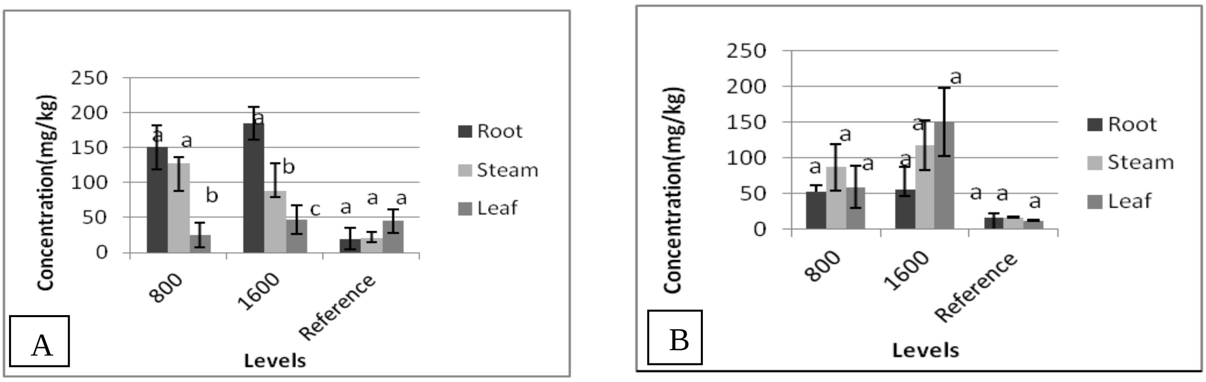

Fig. 1. Comparison of Pb uptake influences of different concentrations of lead nitrate (0,800 and 1600 mg/kg^{-1}) by root, steam and leaf in A: *P. sylvestris*, B: *P. abies* .Data is means of 15 replication ± SE.

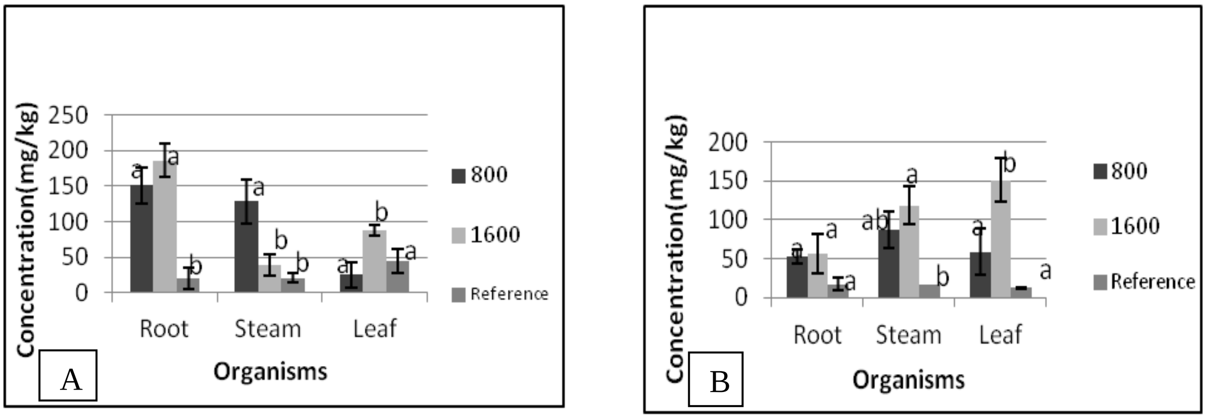

Fig. 2. Comparison of Pb uptake by root in 0,800 and 1600 mg/kg^{-1} treatment, Comparison of Pb uptake by steam in 0,800 and 1600 mg/kg^{-1} treatment and Comparison of Pb uptake by leaf in 0,800 and 1600 mg/kg^{-1} treatment in A: *P. sylvestris*, B: *P. abies* .Data is means of 15 replication ± SE.

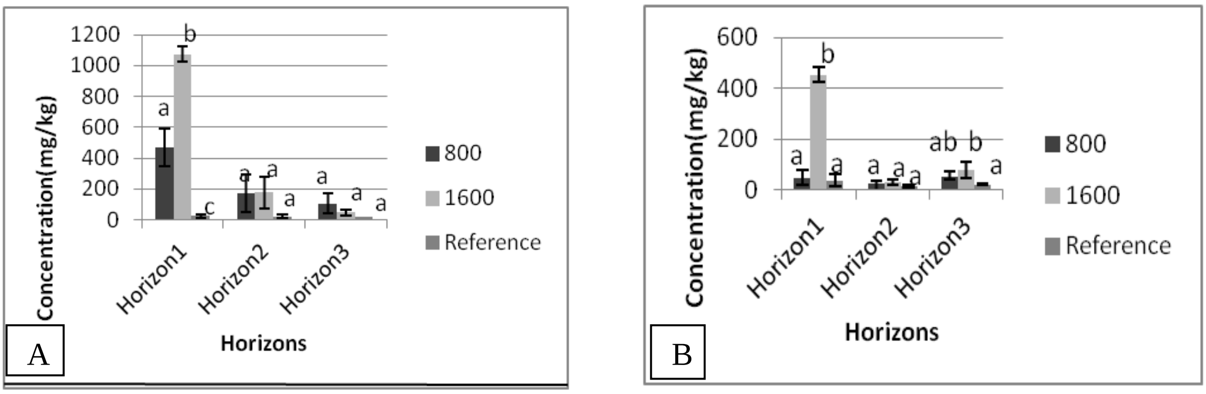

Fig. 3. Comparison of remained Pb in different concentrations of lead nitrate (0,800 and 1600 mg/kg^{-1}) in each horizontal layer of soils of A: *P. sylvestris*, B*: P. abies.* Data is means of 15 replication ± SE.

The Comparison of Pb uptake at different concentration in *P. sylvestris* indicated that at 800 mg kg^{-1} treatment Pb has been accumulated in both roots and stems while at 1600 mg kg^{-1} the high amount of Pb transferred to leaves.

In *p. abies* Pb had not been accumulated in root but its high amounts in1600 mgkg^{-1} dosage was observed in leaves. It seems that when the Pb concentration is more than plant's tolerance it is accumulated in leaves to remove it by leaves falling. It could be concluded that if the aim of phytoremidation is the accumulation of Pb in the roots and stems, the Pb concentration more than 800 mg kg^{-1} isn't suitable for accumulation in stem. The Pb accumulation at 1600 mg kg^{-1} in roots is more than stems, which agrees with Mojiri's (2011) findings on corn. Hyper-accumulators are defined as plants that contain in their tissue more than 1,000 mg kg^{-1} dry weight of Ni, Co, Cu, Cr, Pb, or more than 10,000 mg kg^{-1} dry weight of Zn, or Mn (Steele & Pichtel 1998, Pal *et al* 2010).

Comparison between Pb uptakes through leaves stems and roots of two species in different levels of treatments showed no significant difference (related data not presented).

Reimann *et al*., (2001) indicated that none of the studied plants in northern Europe, including *Picea abies* and *Pinus sylvestris* has an effective role in Pb uptake and their bud could not store a significant amount of Pb.

Turpeinen (2000) suggested that pine seedlings decrease solubility and excitability of Pb in contaminated soil of Boreal forests. In other word, plants with deep roots such as *P. sylvestris* can be used to reduce Pb amount from contaminated groundwater and store it in their organs, similar to our results.

Perveen *et al*., (2011) studied Pb phytoremediation potential in *Jasminum saambac* and showed this plant accumulated Pb in root, leaf, and stem, but the amount of accumulation in flower was low. The Pb (II) accumulation was found dependent on soil pH and Pb(II) concentration in industrial wastewater.

Comparison between the remaining Pb in different treatment levels of each horizontal layer of soil in *P.sylvestris* seedlings showed there was a significant difference only in first layer of soil (Fig. 3A) and the highest amount of Pb in observed in the first layer in 1600 mg kg^{-1} treatment. In other species, *P.abies* there were significantly differences in horizons first and third (Fig. 3B) , as in first layer amount of Pb was in 1600 mg kg^{-1}higher than 800 mg kg^{-1} and control. However in third layer, the difference was significant between 1600 mg kg^{-1} and 0 mg kg^{-1} of lead nitrate. This results showed that *P.abies* in contaminated soil with $Pb(No3)_2$ 800 mg kg^{-1} was useful for soil phytoremediation but their leaves became yellow and this seedlings death.

Water soluble and exchangeable leads are the only fractions readily available for uptake by plants. Oxyhydroxides, organic, carbonate, and precipitated forms of lead are the most strongly bound to the soil. The capacity of the soil to adsorb lead increases with increasing pH, cation exchange capacity (CEC), organic carbon content, soil/water Eh (redox potential) and phosphate levels. In the natural setting, lead hyper-accumulation has not been documented. However, certain plants have been identified which have the potential to uptake lead (Henry 2000). Aldrich *et al*., (2004) studied the effect of Pb uptake and EDTA on Pb concentration in Prosopis. Their results indicated that this species accumulated high amount of Pb in areal organs and by increasing pollution from 25 to 75 mg l^{-1}, the Pb uptake increased, too. Succuro (2010) showed that three cattails (*Typha latifolia)* can remove Pb from the environment in larger quantities if a chelating agent is present in a short period of time. In conclusion, *P. sylvestris* is more suitable for Pb phytoremediation than *P.abies* in soil.

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