Metal uptake by psyllium (*Plantago ovata* L.) treated with lead (Pb) under semi-arid conditions

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**ABSTRACT**

Psyllium plants were treated with different doses of lead (Pb) and different plant parts and seeds were analyzed. Iron (Fe) contents were found to be lower than the toxic level (Soil 2396.9, seeds 691.5, roots 1516.6, leaves 1384.5, husks 1226.1 µmol kg⁻¹ DW). The leaf Zn contents were above the critical level but lower than the toxic level (295.2 ± 16 µmol kg⁻¹). Leaf manganese (Mn) and Cr levels in *P. ovata* plants fell within the critical range (232.6 and 0.1923 µmol kg⁻¹ respectively). Lead in soil significantly correlated with Fe and Mn, but non-significantly with Zn and Cr in plants of *P. ovata*. The transfer ratios of Cr and Zn in plants without Pb treatment were lower as compared to plants treated with varying levels of Pb. *P. ovata* can grow in soils having lead concentration up to 4000 µmol and act as a hyper accumulator of lead.

**Key words** Heavy Metals, Medicinal plants, *Plantago ovata*, Treatment of lead.

**INTRODUCTION**

Soil bionetwork all-over the world is becoming polluted with heavy metals due to a variety of human actions. The association of metals in food chain causes many health hazards for humans (Zahir *et al*, 2009). Land pollution with heavy metals is mounting and has become hard question in many countries including Pakistan wherein most of the crops including medicinally important ones contain high amounts of different metals (Bhutto *et al*, 2009). Of a number of medicinal plants being grown in arid and semi-arid regions, ispagol (*Plantago ovata* L.) has gained much ground due to its multiple benefits to humans (Khinchi *et al*, 2011). For example, its husk and seeds contain a variety of compounds and nutrients due to which these parts are used extensively in pharmacology and healing swellings of the mucous membrane of gastro-intestine, piles, unrelieved constipation, duodenal ulcers and dysentery (Bannayan *et al*, 2008; Khinchi *et al*, 2011) and it is exported to different countries in the world. At present, adulteration of soil in cultivated fields with noxious heavy metals has appeared as a new menace to agriculture (Singh *et al*, 2007; Ahmad *et al*, 2012; Khan *et al*, 2012, 2013). Lead is extensively utilized in battery industries, pigments, photographic resources and paint industry (Martins *et al*, 2006; Parvathi *et al*, 2007). From these sources Pb easily reaches most of the farm fields due to man-made waste mismanagement. Thus it leads to high accumulation of Pb in farm fields adversely affecting growth and production of most crops including medicinal ones. It is highly likely that psyllium, a chosen medicinal crop of arid and semi-arid regions is also adversely affected by heavy metals including Pb.

The present study intended to examine up to which psyllium crop accumulates different types of metals in its different parts after treated with Pb. It was also examined that how far metal contaminated psyllium could pose health hazards to humans living in District Sargodha, a semi-arid region of the Punjab Province of Pakistan.

**MATERIALS AND METHODS**

In order to examine the mineral status in psyllium (*Plantago ovata* L.) different doses of lead (Pb) were applied to the growth medium. The minerals under examination were Fe, Mn, Cr, and Zn. The study was performed at the University of Sargodha (32°82’03” N, 73°72’03” E), Sargodha, Pakistan, from December 2011 to March 2012. In Pakistan, Sargodha has been ranked as the 5th most contaminated urban city of the Punjab province by the Punjab Environment Protection Department (Tahir, 2007). Fifteen seeds of psyllium (*Plantago ovata* L.) were sown in each of earthen pots containing clay-loamy soil (7 kg). The average day and night temperature was 20/18°C. Irrigation was practiced with good

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quality water when required. Thinning of seedlings was carried out 5 days after their appearance and 10 plants were kept per pot up to maturity. All sound management procedures were adopted to ascertain a good crop. After 30 days of seedling emergence, different concentrations of lead (0, 500, 1000, 2000, and 4000 µM) were applied using lead nitrate as a source of lead. There were five replications within each treatment. For sampling, leaves and roots were rinsed thoroughly with distilled water to make dust free leaf surface. After this, all leaf, root, seed, husk and soil samples were oven-dried at 65 °C. The dried samples were ground to powder for the analysis of metals.

**Wet acid digestion:** The dried (0.1 g each) and ground samples were taken in small beakers and kept them overnight at room temperature, after adding H₂SO₄ (2 ml). Hot plate digestion was carried after further 1.5 ml H₂O₂ to each beaker. After complete digestion of all samples, the volume was raised to 50 ml with distilled water. Iron, Mn, Zn and Cr in the digestd samples were appraised using an atomic absorption spectrometer (Model # AA. 6300 SHIMADZU). The precision and accuracy of analysis was assured through repeated analyses of samples against National Institute of Standard and Technology, Standard Reference Material (SRM 1570) for all metals studied. The results were found within ± 2% of the certified value. Internal reference standard materials and reagent blanks were also employed in the process of analysis to ensure the precision and variations below 10% were considered correct.

**RESULTS AND DISCUSSION**

**Soil:** The concentration of Fe in soils varied significantly with increase in soil Pb level. The highest level (2396.9 µmol kg⁻¹) of Fe was observed at 4000 µM Pb i.e. 2396.9 while the lowest value (2304.4 µmol kg⁻¹) was observed at 1000 µM Pb. However, in contrast, the soil Mn levels did not vary significantly at varying external Pb regimes (Fig. 1). A highly significant (P ≤ 0.001) effect of varying soil lead concentrations was observed on soil Zn levels (Table 1). The highest concentration of zinc (809.5 µmol kg⁻¹) was observed at 0 µM Pb while the lowest value (611.6 µmol kg⁻¹) at 4000 µM soil Pb, which indicated that as the concentration of soil lead increased Zn uptake decreased. However, the soil chromium (Cr) concentration did not vary significantly at varying soil Pb regimes (Fig. 2).

**Leaves:** Exogenously applied Pb to psyllium plants significantly altered leaf Fe, Mn, and Cr concentrations. In contrast, the leaf Zn concentration did not vary significantly at varying soil Pb regimes (Table 1). Highest leaf Fe concentration (317.2 µmol kg⁻¹) was recorded at 500 µM Pb, while the lowest (1384.5 µmol kg⁻¹) at 4000 µM soil Pb. This showed that leaf Fe concentration decreased with increase in external Pb level. The highest leaf Mn concentration was recorded to be 295.3 µmol kg⁻¹ (Fig. 1). However, the leaf Cr concentration increased with increase in external Pb level (Fig. 2).

**Roots:** Psyllium plants treated with varying levels of Pb showed non-significant effect on root Fe concentration. Highest root Fe concentration (1801.9 µmol kg⁻¹) was recorded at 1000 µM of Pb. The root Zn concentration increased consistently with increase in Pb level of the growth medium. A significant effect of external Pb levels was observed on root Mn and Cr concentration. The
concentrations of root Mn and Cr increased consistently with increase in Pb level of the growth medium.

**Seeds:** Lead treatments of the growth medium had non-significant effect on seed Mn concentrations, whereas they significantly altered the amounts of Fe, Zn and Cr in roots. Generally, root Zn, Fe and Cr concentrations decreased with increase with external Pb level.

**Husk:** The different lead treatments did not affect the husk for Fe, Zn and Mn concentrations, whereas they significantly affected husk Cr concentrations in *P. ovata* plants. Generally, husk Cr concentration increased due to exogenously applied Pb to the growth medium.

There is a correlation co-efficient between the concentrations of different metals in soil and the psyllium plants. However, soil Pb was negatively correlated with plant Fe (-0.521; *P* ≤ 0.01), Mn (-0.432, *P* ≤ 0.05) and non-significantly correlated with plant Zn (-0.028). There was a positive but non-significant correlation between soil Pb and plant Cr (0.008, *P* ≤ 0.05).

The soil Fe concentrations determined in the present study was above the critical level (44.76 µmol kg⁻¹). Similar soil Fe levels have been earlier reported by Viets and Linsay (1973). Although, Campose (1997) reported high levels of Fe in soil, the soil Fe levels recorded in the present study were much greater than the critical level. Zinc is also known for its limited mobility in plants and instantly it accumulates in roots when it is added to the soil (Rinne, 1960). The low accessibility of Zn to the plant is ascribed to iron oxide (FeO) in the rhizosphere (Dabkowski-Naskret *et al.*, 2004). However, availability of Zn in the soil of Konya Closet Basin for plants reported by Gune *et al.*, (2004) was lower than the values recorded in the present investigation. Excessive amount of Zn has been reported to reduce root growth in the sensitive plants (Ruana, 1988). Soil Cr levels found during our investigation were higher than the critical level (85.2 µmol kg⁻¹) reported by Rhue and Kidder (1983). Values of Mn in soils of the Spanish Mediterranean region reported by Marin *et al.* (2000) were much higher than those reported in the present investigation. It is believed that pH of soil in organic matter may increase Mn solubility which make it available for plants (Espinoza *et al.*, 1991; Pastrana *et al.*, 1991).

The plant iron concentration was significantly higher than the optimal Fe values (895.25 µmol kg⁻¹) reported by Jones (1972). The higher forage Fe concentration was reported in Indonesia (Prabowo *et al.*, 1990) and Philippines (Orden *et al.*, 1999). Higher Fe contents in forage may cause toxicity in grazing animals and values close to 2345.6 µmol kg⁻¹ of Fe may cause severe toxicity (Grace, 1983). In soils the Fe level was found almost near the toxic level (Grace, 1983). In seeds (except in control) Fe concentrations were lower than the critical value (Jones, 1972) that is not adequate (McDowell *et al.*, 1985; Khan *et al.*, 2005). High levels of Fe found in this study are in agreement with the higher forage Fe value reported by Khan (2003) in Pakistan. The dietary limit of Fe in the food is 179.0 - 1074.3 µmol/day (Kaplan *et al.*, 1993).

**Husk:** The different lead treatments did not affect the husk for Fe, Zn and Mn concentrations, whereas they significantly affected husk Cr concentrations in *P. ovata* plants. Generally, husk Cr concentration increased due to exogenously applied Pb to the growth medium.

<table>
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<tr>
<th>Figure 1</th>
<th>Relationship between means of Fe and Mn (µmol kg⁻¹ DW) in soils, seeds, leaves, roots and husk of <em>P. ovata</em> plants on different Pb doses</th>
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<tr>
<td>Figure 2</td>
<td>Relationship between means of Zn and Cr (µmol kg⁻¹ DW) in soils, seeds, leaves, roots and husk of <em>P. ovata</em> plants at different doses of lead</td>
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The transfer ratio is the ratio of the absorption of the metal by the plants to the absorption of the metal in soil. The transfer ratios of Cr and Zn in plants from the control soils with lower concentrations of Pb were lower than those from the soils with higher metal load. The transfer ratios of Fe and Mn in plants from the control soils with lower concentrations of the metal were higher up to \( T \), (2391.2 ± 132.7 µmol kg\(^{-1}\)) than those from the soils with higher metal load. This shows that various soil features other than the total soil metal contents affect the rate of metal uptake by plants. Addition of a small amount organic matter to soils lowers the absorption of metals by adsorption and precipitate formation (Mench et al., 1994; Chen and Lee, 1997) thereby causing their unavailability to plants. Similar effects on the metals (Fe, Mn, and Ni) were studied (Mench et al., 1994; Chen and Lee, 1997) i.e., lower transfer ratios in the soils of different metal treatments than the control soils were observed. pH is one of the promising factors that affect metal accessibility in soil. Metal accessibility generally declines with increase in soil pH due to insoluble organic complexes (Smith, 1996). This relationship between metals in soil and those in medicinal plants showed that the cause of contamination resulted from the factors prevalent at the study site.

**Conclusion**

The present investigation was carried out to observe the metal profile in which the Cr, Fe concentration was higher than the critical values. The Zn concentration was also higher which restricted the root growth. Various soil properties affect the metal uptake by the plants but addition of the organic matter reduces the metals absorption.

**REFERENCES**


