Study of Lead Toxicity Mitigation in Soil in the Presence of Organic Matter

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Abstract—**Soil contamination with lead (Pb) has become a common problem in many farmlands and natural ecosystems as well. Thus, the contamination of food produced in those farms has become a serious concern. For the study, twenty-four permanent plots were chose in the forested area. Three treatments, addition of compost, mycorrhizae, compost with mycorrhizae, and a control used. The indicator plant that used to identify the response to soil Pb, was Anthemis Anthemis. Treatments applied to 5 randomly selected Anthemis Anthemis of approximately 0.5m height residing in each plot. Soluble soil Pb and soil organic matter (SOM) compared using soil samples collected at 0.20m depth level. Soil samples collected three times. Foliar samples from "treated" plants analyzed for Pb. During the experimental period, the selected samples closely monitored and changes in health were duly recorded. Effect of standard compost and mycorrhizae on protecting samples from stressful conditions was significant (p<0.001). The results from soil and foliar analysis revealed the status of Pb contamination during rain, which appears to have links with the death of Anthemis Anthemis plants. Positive correlations between soil Pb and leaf Pb were significant (p=0.001). Soil amendment with compost and mycorrhizae reduced the Pb content below the threshold levels (p=<0.001). Application of compost and mycorrhizae appeared to be effective in reducing Pb toxicity in the soil. Soil improvement with standard compost and mycorrhizae appears to be effective in treating contaminated soils with Pb.**

Index Terms—**Golestan, soil contamination, lead, compost, mycorrhizae.**

I. Introduction

Heavy metals contamination is a major problem of our environment and they are the major contaminating agents of our food supply [1]. This problem is receiving more and more attention all over the world, in general and in developing countries in particular. The biological half-lives of these heavy metals are long and have potential to accumulate in different body organs and thus produce unwanted side [2]. Lead is the most toxic and the most abundant metals in food. Excessive accumulation of these heavy metals in human bodies creates the problems like cardiovascular, kidney, nervous and bone diseases [1], [3]. Contamination of soil with lead has occurred on a global scale. Exposure to lead may cause adverse effects to human health and the environment. Heavy metals such as Pb become toxic when they do not metabolized by the body and end up accumulating in the soft tissues. Ingestion is the most common route of exposure to Pb. In plants, uptake of Pb depends on the plant species and bioavailability of Pb in the soils. Since most of the ingestion of Pb occurs from consumption of plants, then addressing how Pb become unavailable for plants can aid in controlling Pb toxicity. High concentrations of heavy metals in soils often characterize industrial and postindustrial regions. Sites located around the smelting industries

may have extremely high levels of toxic metals accumulated in soil, particularly in the upper layers. Although the levels of toxic pollutants emitted into the atmosphere have decreased, heavy metals accumulated in soils may persist and affect terrestrial ecosystems for a long time. Vehicle emission where Pb containing gasoline is used contributes to toxic metal and soil pollution. For busy roads, Pb levels in soil and vegetation indicated a significant level of Pb pollution in the areas nearby [3]-[5]. One study has proved the presence of many trace metals in both leaded and unleaded petrol, diesel oil anti-wear substances added to lubricant, brake pads and tires and emission of them through vehicle exhaust pipes. A great part of metal pollutants are deposited in adjacent soils, where they may be transformed and transported to other parts of the environment, e.g., to vegetation. In addition to soil, forest vegetation in particular acts as a sink for atmospheric pollutants because of its capacity to act as an efficient interception to airborne matter [6]. Soil organic matter (SOM) is, together with soil pH, the most important parameter controlling toxic metal behavior in soils. Toxic metals bound on insoluble humic substances (i.e. an important fraction of SOM) are relatively immobile. On the other hand, binding on smaller organic molecules may increase metal mobility and bioavailability (e.g. [7]). Sorption sites on organic matter can be highly specific [8], [9] reported high ability of Pb to form complexes with insoluble humic substances of low molecular weight. Humic carboxylic -COOH and phenolic-OH groups are mainly involved in the formation of metalhumic complexes [10]. The strength of metalhumic complexes influenced by soil pH and ionic strength [8], [11] and [12]. Binding on humic acids may enhance metal sorption on mineral particles [13]. Detailed knowledge of the interaction of toxic metals with humic substances in soils could be used in the development of remediation methods for polluted soils [14]. Mycorrhiza considered crucial component of soils that provide immunity for the plants growing in contaminated soils [15]. In addition to its role played in the provision of essential plant nutrients from the soil and saving the plants growing on dry soils, mycorrhizae help the plants to escape from heavy metal toxicities [15]. Numerous studies conducted collecting lead concentration data from both natural and contaminated soil

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on a range of scales. However, little attention have been paid to practical ways of transforming available Pb for plant to unavailable forms in soil. Present research done to study of compost effectiveness to control of Pb toxicity in soils.

II. Material and Methods

The area selected for the study is believed to be one of the most affected area by Pb contamination in soils [16]. Experimental area, Golestan national park witch situated in Golestan Province between the eastern parts of the Elburs Mountains and the western fringes of the Khorasan-Kopet Dag . The Golestan National Park was the first area in Iran to be designated as a national park that is located at 37, 16 ° to 37, 36 ° north latitude and 55, 44 ° to 56, 17 ° east longitude and has an area of about 91.000 hectares. The terrain is mountainous with altitude varying between 380 and 2819 meters [17].

Annual rainfall in the region is about 650 mm [17]. Temperatures are low, with an annual mean of 12 ℃, and ground frost is common in February [17]. Ultisol Soil characterized by a thick, black, organic layer at the surface [17]. Twenty-four permanent plots of 20 m x 20 m established to represent an affected area in the Golestan National Park. Randomized Complete Block Design (RCBD) used with three replications. A sketch of the area and the experimental plots mapped using GPS (Global Positioning System) points with 20 cm accuracy. The indicator plant used to identify the response to soil Pb was Anthemis Anthemis. Treatments applied to five randomly selected Anthemis Anthemis plant. They selected from each sampling plot. Four soil amendments (a). Compost-2kg/plants, (b). Compost and mycorrhizae-4kg/plants. (c). mycorrhizae-2kg/plants including a control were used for the study. Lead in the soil samples was measured by wet ash method [18] and the extractants analyzed for the above elements by Atomic Absorption Spectrophotometry [19]. Soil sampling s done three times and the samples collected from 0.2 m depth and 0.3m-0.5m away from each plant. Death rates of the plants calculate by keeping records of the selected samples throughout the experimental period and counting the deaths at the end of the trial. SPSS statistical software used for the analysis of variance (ANOVA), t-test and regression analysis of the results.

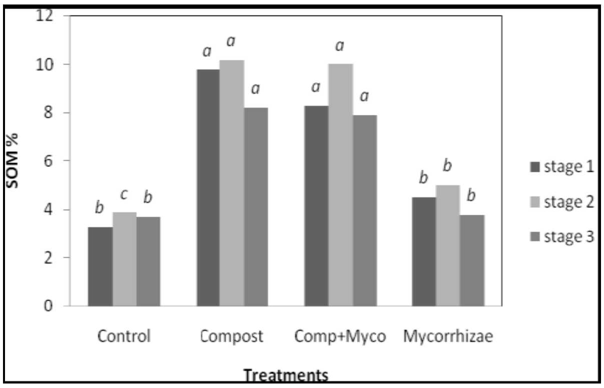
III. Results

The results showed based on the work done during the one-year study period in the Golestan National Park ,Iran Average values of the parameters were used to compare the effect of different treatments.

A. Soil Organic Matter

Addition of compost to soil increased SOM content in the soil (see Fig. 1). In addition, the effect of the treatments on SOM content was significant for all the four stages of sampling– e.g. Stage-1 (p=<0.001), Stage- 2 (p=<0.001), and Stage-3 (<0.001) at the 0.2m depth.

Treatments with mycorrhizae and the control showed the lowest SOM at all three stages. Across different stages at 0.2m depth, the highest SOM content exhibited in the Stage 2 but the statistical analysis under α level of 0.05 was not significant.



(Mean comparison was done for different seasons separately and the means appear with same letter were not significant at p<0.05)

Fig. 1. Status of SOM percentage among the treatments at three different stages of sampling in 0.2m depth.

B. Lead in the Soil

Results from both soil and foliar analysis clearly indicated the status of contamination of soil and the vegetation with Pb in Golestan park differences among the treatments were observed in terms of soil Pb level in 0.2m depth during Season-1 (p=0.01), -2 (p=0.004) but there was no significant influence detected at Season-3 (p=0.79) (see Fig. 2). The highest Pb content detected in the control during Season-1 whereas, the lowest observed under the treatment mycorrhizae, again during Season-1. However, the control showed the highest soil Pb level during the Season-1 while the treatments compost, compost with mycorrhizae, and mycorrhizae showed significantly lower soil Pb levels compared to the control.

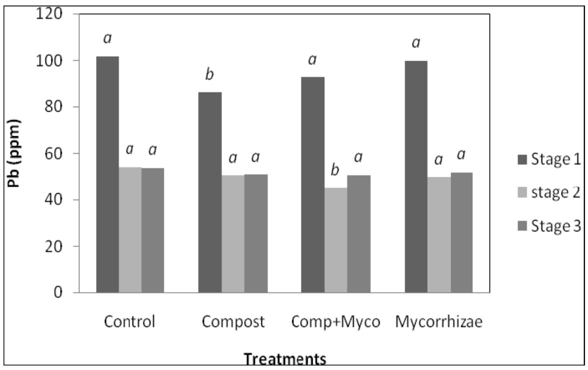


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Fig. 2. Status of Pb among treatments at three different stages of sampling in 0.2m depth.

C. Pb in the Leaves

TABLE I: Variation of Pb in the Leaves from Different Treatments

treatment	Control	compost	Compost+ mycorrhizae	mycorrhizae
Pb(ppm) Mean	4.133(0.04)	2.1(0.0)	4.217(0.05)	4.217(0.02)

*Standard error for the respective mean given within brackets

Results from foliar analysis indicated the entry of Pb into the plant bodies (see Table I). When the levels of Pb in the soil considered, plots treated with mycorrhizae showed lower values when compared to the values observed in the other plots. Even though this decline was not statistically significant (p=0.075) under α level of 0.05, the results cannot be disregarded.

D. Death Rate of Anthemis Anthemis Plants

Soil amendments with standard compost and mycorrhizae are effective in controlling the death of Anthemis Anthemis plants. Treatment effect on the death rate of samples was significant (p<0.001) and the control showed the highest death rate (see Table II).

TABLE II: VARIATION OF DEATH RATE OF ANTHEMIS ANTHEMIS PLANTS

treatment	control	compost	Compost+ mycorrhizae	mycorrhizae
Death rate (%) (Mean)	46.67(8.43)	15.83(0.40)	17.67(0.92)	31.67(3.07)

*Standard error for the respective mean given within brackets

E. Lead in the Soil and Death of Plants

The relationship between Pb concentration and the death rate of Anthemis Anthemis samples was significant (p<0.001) while the correlation showed the death rate of samples has been largely affected by the Pb concentration in the soil (see Fig. 3). Therefore, the death rate of the samples used for the experiment appeared to have increased with the increasing availability of Pb in the soil. Results further revealed that the crucial level of Pb in relation to the survival of Anthemis Anthemis samples was around 60 ppm in the Golestan national park soil and beyond this level; even a slight increase of available Pb in the soil may impose severe damages on plant's metabolism leading to dieback. The results are in agreement with the work done by [20].

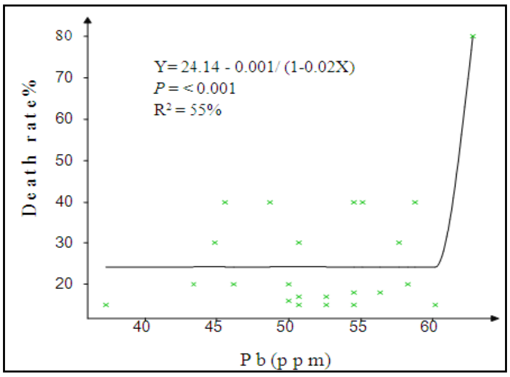

Fig. 3. Pb concentrations in the soil Vs Death rate of plants.

F. Lead (Pb) Concentrations in Soils vs Pb Concentrations in Foliage Parts

Parallel to the increment of Pb levels in the soil, the Pb level in the leaves of Anthemis Anthemis plans have also increased. The relationship between soil Pb and the leaf Pb was significant (p=0.01) and the nature of the relationship is linear – by –linear (see Fig. 4).

G. Soil Organic Matter vs Pb in the Soil

The content of soil Pb is inversely proportional to the SOM content and the relationship between them was statistically significant (p=<0.001). The findings indicate that the availability of Pb in the soil for plants in the can be reduced by increasing SOM level. The nature of the decline of Pb with the increasing SOM level seems to be linear by linear (see Fig. 5). Immobilization of soluble Pb in the soil by the humic and fulvic acid molecules presented in some documented studies by several researchers (e.g., [21]).

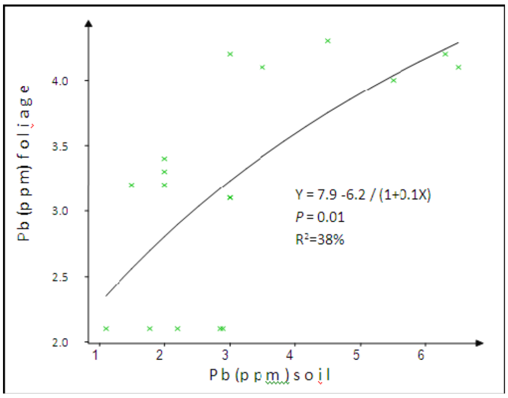

Fig. 4. Pb concentrations in soils Vs Pb concentrations in foliage.

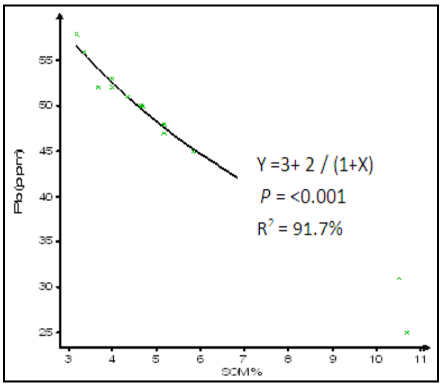

Fig. 5. Soil organic matter Vs Pb in the soil at four different stages.

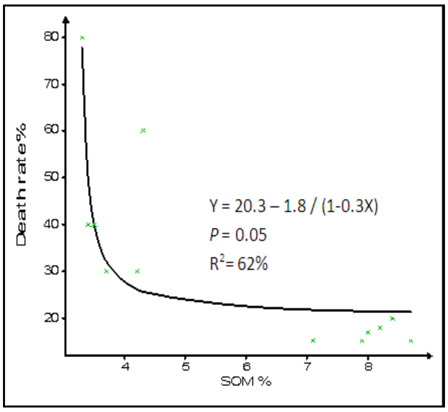

Fig. 6. Soil organic matter content in the soil vs Death rate of plants.

H. Soil Organic Matter Content in the Soil and Dieback of Plants

Results showed that the increase of SOM level helps to reduce the death of plants. The relationship between SOM level and the death rate of samples (Anthemis Anthemis) was significant (p=0.05). The nature of the relationship seems to be linear-by-linear and it further indicates that by maintaining SOM level somewhere above 4%, the death rate of samples can reduce significantly (see Fig. 6).

IV. DISCUSSION

Deterioration of the level and the quality of soil organic matter in terms of humic substances appears to have influenced on the development of Pb toxicity. The death of plants may be related to dozens of reasons, which include Pb toxicity as well. Effect of the treatments consisted of SOM justify the argument. One of the most important fractions of SOM, the humic substances, is highly effective in neutralizing the effects of toxic substances (e.g. Pb) in the soil [21]. The lower the level of SOM, the higher the level of plant available soil Pb and therefore, the enrichment of soils in affected areas with quality organic matter with standard levels of humic substances can be recommended to control Pb toxicity in the soil. This argument confirmed by the death rate of the samples where the results show that the lowest level of SOM represents the highest death rate. The level of soil Pb has gone up to 106 ppm. However, it should be noted that the maximum allowable limit for soil Pb is about 100 ppm [22]. Even the smallest amount of Pb may impose severe damages on plant's metabolism leading to death. Lead (Pb) at toxic levels identified as an agent causing damages on plants' respiratory mechanism in particular. [20]. Burning diesel, gasoline and lubricants releases Pb to the atmosphere. Additionally, the frictions in brake pads, clutch liners and tires release these elements to the atmosphere. Flows of water flood from rainfall seem to be the most possible transportation source of Pb from the polluted part. Following last studies, Pb subjected to long-range atmospheric transportation to greater extent [23] where Pb can transport for a distance greater than 120km [24]. Therefore; it is very unlikely that the rain falling onto the area is free from Pb. When the levels of Pb in the soil are considered, plots treated with mycorrhizae showed lower values than the values observed in the other plots. Even though this decline is not statistically significant for less than α =0.05, the results cannot be ignored. Mycorrhizae significantly increase the absorption of various elements from the soil including heavy metals such as Pb [25]. Therefore, it can be assume that mycorrhizae are responsible for reduction of Pb in the soil treated with mycorrhizae. Mycorrhiza considered a crucial component of soils that provide immunity for the plants growing in contaminated soils [15]. Therefore, mycorrhizal treatment may have been effective in increasing the tolerability of plants growing in contaminated soils with Pb.

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