"Phytoremediation of Agricultural Land Polluted with Heavy Metals in Wadi Alsamin - Hebron-Palestine"

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2012

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معالجة التربة الملوثة بالعناصر السامة في منطقة واد السمن- الخليل- فلسطين باستخدام النباتات

Murad Alhousani

This thesis was submitted in partial fulfillment of the requirements for the Master's degree in Environment and Water Sciences

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Date of Defense: December 18th 2012

The findings, interpretations and conclusions expressed in this study do not necessary express the views of Birzeit University, the views of the individual members of the M.Sc. committee or the views of their respective employers

Abstract:

Green technology "phytoremediation" approach was applied in Wadi Alsamin in Hebron-Palestine to evaluate the plant efficiency in remediation of polluted soil. An open field controlled experiment was conducted to assess the efficiency of two plant species namely: corn (*Zea mays*) and tobacco (*Nicotianatabacum*) plants for bioaccumulation of heavy metals under natural growth without chemical assistance. The concentrations of three heavy metals (Cr, Mn, Zn) were determined in all plant parts (root, stem, leaf and fruit) for both plants by using Inductively Coupled Plasma–Atomic Emission Spectrometry (ICP-AES). The accumulation of heavy metals in leaves was higher than in the other parts for both plants. The bioaccumulation factor (f) of corn plant for Cr as a pollutant metal 0.05 was higher than in tobacco 0.02 while bioaccumulation factor (f) for Mn in tobacco 0.13 was higher than in corn 0.09 where bioaccumulation factor (f) for Zn in both plant was 0.3.

To My Parents

Acknowledgments

It's a great feeling to write this word especially to express my gratitude and thanks to the team who encouraged and supported me in accomplishing this modest effort.

Dr. Jamil Harb, I would like to thank you for your direction which motivated and trained me to improve the quality of my research. Your insight and experience were so valuable for me that reflect deeply on research skills.

I would like to take the opportunity to thank my thesis examination committee Dr. Nidal Mahmoud, Dr. Rashed Al-Sa`ed and Dr. Jamil Harb

Mr. Jamal Talab, general director of Land Research Center - LRC, special thanks for your always encouragement and support. Actually, you have a vital role in my ability to over many obstacles and difficulties that had faced me in my research and I want to thank LRC team specially Mr. Mohammad Al Amleh – GIS and mapping unit- LRC.

Dr. Ahmad Abu Obaid, An-Najah National University, deeply appreciate your valuable directions and cooperation which enrich my research.

Special thanks for Dr. Zakariyyah Salawdah- the Palestinian Ministry of Agriculture, who support and encourage the research idea.

Also I would like to express my sincere and thanks to Dr. Ayman Salah for your support.

Dr. Husam Saed, many thanks to you. Your valuable direction and continuous advice were reflected deeply on my research.

This study was funded by GEF-UNDP and Land Research Center "LRC". The researcher would like to thank Mr. Jamal Talab and Mrs Nadia Alkhudari for their assistance and support.

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1 Introduction

1.1 Problem Statement

The problem of land pollution caused by waste water originating from the remnants of wastewater in the industrial part of Hebron which is considered the most serious environmental problem facing the region of south Hebron. The local wastewater stream known locally as “Wadi Alsamin” already destroyed thousands of dunums of agricultural land. That valley has been the basket of field crops in the region which have been contaminated with chemicals mainly heavy toxic elements and waste sludge. Consequently, farmers abandon their lands. Farmers' opinions have been explored about this issue through field visits where the farmers agreed on the importance of urgent need for remediation of their lands.

1.2 Research Objectives

The main objectives of this research are:

1. To evaluate the levels of heavy metals in the polluted soils.
2. To investigate the extent of plant efficiency in the remediation of the polluted soils in Wadi Alsamin.

1.3 Research Motivation

Untreated wastewater in Palestine usually flows in agricultural and open natural lands. This problem creates two important issues. First, it makes farmers use this untreated wastewater for agricultural production. Farmers believe that untreated wastewater is a good fertilizer, without any consideration to the pollutants, either organic or inorganic. Second, it destroys the agricultural soil and reduces its fertility as a result of the accumulation of pollutants in soil profile. Therefore, this research was done to evaluate and monitor an environmental friendly technique known as "phytoremediation" to remediate polluted soils.

The main hypothesis of this work is that remediation of polluted soil could be done by crops.

1.4 Location and Site History

Wadi Alsamin in the southern part of Hebron city represents an open channel for the municipal wastewater with length of 44.3 km and width exceeding 70 m in some areas. The stream starts flowing from Khalit Aldar area, southeast of Hebron city, (797 m above sea level) and passes through 18 Palestinian residential communities that are located on the stream bank and reaches Aldahryya area (396 m above sea level) (Figure 1). Wastewater of the stream is collected and treated in the Israel wastewater treatment plant (Shouket) in Bersheva area, and reused after that for agricultural purposes.

The negative environmental impact of "Wadi Alsamin" wastewater increased progressively as it includes the wastes of industrial part in Hebron especially those

originate from tannery factories and cutting stone plants, which discharge their raw wastewater without any treatment. As a result of people's protests, the Hebron Municipality has installed wastewater transmission pipe line for 5.3 km in Khalit Aldar area since 2004. However, the area served by transmission pipe line is left contaminated with wastewater stream. This contaminated land has become unproductive and abandoned by farmers. Accordingly, there is an urgent need to remediate polluted soils in Wadi Alsamin.

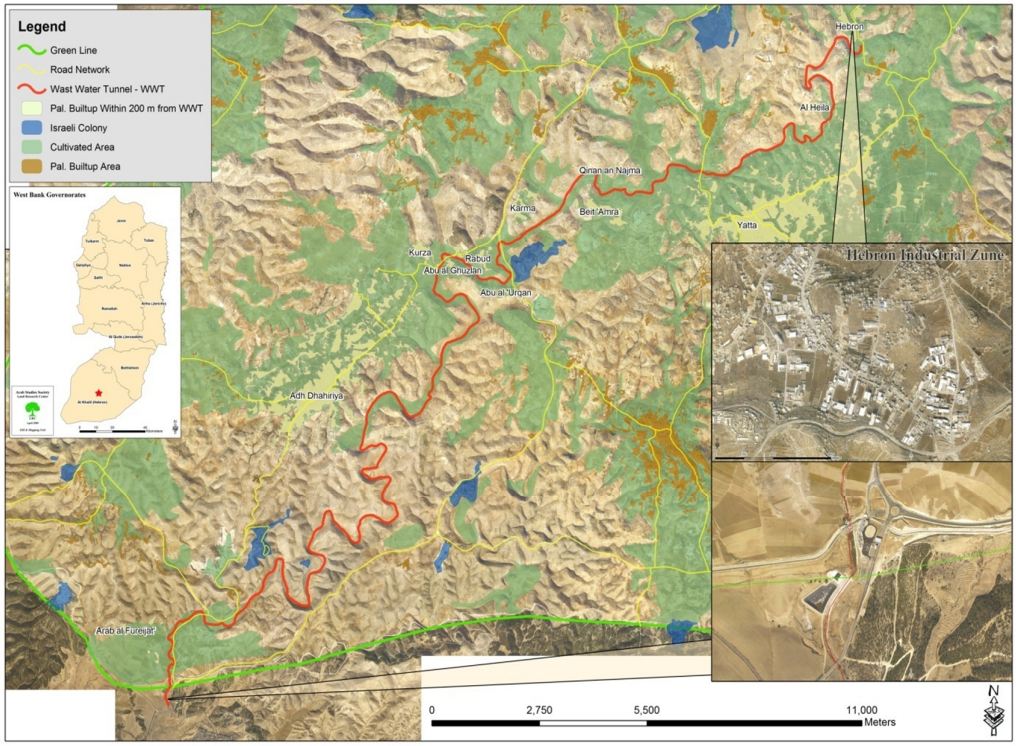


Figure 1: Wastewater Stream in WadiAlsamin- Hebron

Source: Land Research Center - LRC, GIS and Mapping Unit, 2012

1.5 Literature Review

1.5.1 Phytoremdiation

Phytoremediation is a cost-effective, ecologically safe and environmentally sound technique that is prescribed as 'environmental medicine' [1]. The principal concept of phytoremediation is the use of plants to remove pollutants from the environment [2]. The use of plants and other organisms to remediate soil is an alternative or complementary technology for engineering-based remediation methods which could be used for pollutant stabilization, extraction, degradation, or volatilization [3]. Accordingly, this effective and affordable technique includes phytoextraction, rhizofiltration, phytostabilization, phytovolatization, and phytodegradation. Phytoextraction technique involves the uptake of pollutants from soil by plant roots into above-ground portions of plants. Rhizofiltration is a water remediation technique that involves the adsorption or precipitation of contaminants onto plant roots. Phytotransformation, is applicable to both soil and water and involves the degradation of contaminants through plant metabolism. Phyto-stimulation or plant-assisted bioremediation, also is used for both soil and water, which involves the stimulation of microbial biodegradation through the activities of plants in the root zone. Phytostabilization approach involves the use of plants to reduce the mobility and migration potential of contaminants in soil [4].

1.5.2 Selected Plants

The selection of plants for phytoremdiation depends on two important points; High yielding plant with moderate metal accumulation and hyperaccumulation capacity of the selected plants [5].

1.5.2.1 Corn

Corn (*Zea mays*) plant grows fast and relatively tolerant to the targeted heavy metals [6]. It can absorb up to 0.1 $mg.kg^{-1}$ of copper, cadmium, chromium, lead, nickel, and zinc. These characteristics qualify corn as a hyperaccumulator [6]. However, corn is capable of continuous phytoextraction of metals from contaminated soils by translocation metals from roots to shoots. Accordingly, corn plants have a high metal accumulating ability in the foliar parts with moderate bioaccumulation factor, which makes this crop a heavy-metal tolerant plant [7]. In addition to that, scientists stated that crop plants such as corn, sunflower, and Indian mustard that show high tolerance to heavy metals are probably able to use the surpluses that originate from soil manipulation [8]. In this sense, corn plant is considered an effective accumulator plant for Cd and Pb from polluted soil [9]. In another study that addressed phytoremediation of contaminated soil by corn plants, corn plants proved their potential as a bioremediation agent for As, Cr and Cu [10].

1.5.2.2 Tobacco

Tobacco plants are identified as hyperaccumulators and useful for phytoremediation [11, 12]. They were considered as potential candidates for phytoremediation for sites contaminated with percholate [13,14]. These plants accumulate Zn, Cu, Mn, Pb and Cd at high amounts in their leaves [15]. Recent researches have focused on modulates tobacco tolerance to heavy metals on selective gene in order to improve the pytoremediation strategies. [16]. Moreover, a combination of using natural chelators with tobacco to enhance the accumulation has been studied [17]. Other studies have addressed the development of transgenic in tobacco plants for specific pollutants to increase the tobacco remediation efficiency for methylmercury, Cd, Ni and Zn [18, 19, and 20]. In this sense one study shows that transformed *N. glauca* of tobacco represents a highly promising new tool for phytoremediation [21].

1.5.3 Heavy Metals

Application of untreated wastewater to soil for long period enriches soils with heavy metals to a concentration that may pose potential environmental and health risks [22]. Accordingly, steps must be taken for efficient treatment of sewage in order to reduce the extent of heavy metal contamination accumulation [23].

The term “heavy metals” is usually linked to metals that are toxic and contaminant. Understanding bioavailability is the key to assessment of the potential toxicity [24]. These heavy metals that present in municipal and industrial

wastes may retain in soil profile and consequently uptake by plants [25]. Accordingly, monitoring heavy metals in soil and plant tissue is an important issue to prevent the buildup of such metals in food chain and soil [26].

1.5.4 Plant Stress and Tolerant

Plant employs various strategies of mechanism that may be involved in the detoxification of heavy metals and thus tolerance to metal stress [27]. The nutrient management is a possible way to overcome metal toxicity. For instance, the uptake of sulfur and assimilation enhance the tolerance for toxicity of Cd [28]. Such mechanisms are mainly based on chelation and sub cellular compartmentalization [29].

The metals are suspected to exert their toxic action on plants through oxidative damage [30]. Accordingly, the anti-oxidative systems of plants have a key role in encountering high concentration of metals as a defense mechanism [31]. Generally, plants activate various cellular mechanisms to regulate the concentration of metal ions inside the cell in order to minimize the potential damage. These mechanisms may involve the detoxification of heavy metals and thus tolerance to the metals stress [32, 33]. Further defense mechanisms include binding of heavy metals to cell wall, and extracellular exudates in addition to reduce the uptake and efflux of metal pumping in the plasma membrane. Moreover, chelating of metals in cytosol by peptides such as phytochelatins, repairing of stress-damage proteins and compartmentation of metals in the

vacuoles are ways to inactivate heavy metals [29]. As an example, high concentration of Mn caused plants to compartmentalize Mn in different organelles of shoot and leaf plant cells [33].

The toxicity symptoms of heavy metals on plants are usually determined by bioindication techniques which are usually based on the recognition of the visible symptoms on plant [34]. Symptoms are seen easily on leaves. Accordingly, they can be used as bioindications to follow up the uptake of heavy metals or for monitoring purposes in a contaminated area [35]. In addition, the reduction in both root and shoot biomass is part of heavy metal stress symptoms [36, 37, 38]. Photosynthesis inhibition, decrease in water potential and an increase in stomata limitation for CO_2 are also affected by toxicity of heavy metals [39]. Some studies have addressed the aspect of cross-adaptation between heavy metals. Pretreated plants with certain heavy metal, like Cd and Ni, increase the plant tolerance to other heavy metals like Cr, Zn, Pb [40].

1.5.5 Industrial and Municipal Wastewater

The Municipal and industrial wastewater contains a mix of toxic heavy metals [41]. As a result, the levels of pollutants generated from industrial waste vary significantly from industry to another [42]. It is known that the heavy metals such as lead, copper, nickel, cadmium, zinc, mercury, arsenic, and chromium are common in waste contaminated soil [43]. Also a major difference is that municipal wastewater heavy metals are usually bound to particulate organic

matter while heavy metals in industrial wastewaters are often present in soluble phase [44]. Accordingly, the use of municipal wastewater in agriculture is wide-spread, and the build-up of certain heavy metals in plants may reach the maximum permitted levels if efficient management is lacking [45, 46, and 47].

1.5.6 Impact of Wastewater on Soil Properties

In general, land use can significantly affect the soil physical, chemical, and biological properties [48]. In particular, the anthropogenic activities have impacts on soil bulk density, microbial biomass and activity, and organic matter [49]. Therefore, the knowledge of soil heterogeneity is necessary to design a soil management practices especially for those affected by wastewater application, [50]. The wastewater effluent is highly alkaline in nature, and contains high levels of minerals, mainly heavy metals, to a point that soil became unfit for soil applications [51]. Wastewater possesses different biological, physical and chemical effects on the soil. The principal effects on the physical properties of the soil are from the salt contents and the suspended solids [52]. The long-term effects of wastewater application on soil are numerous. It decreases the bulk density of soil, resulting in higher total porosity and higher hydrophobicity. Moreover, long-term wastewater irrigation results in higher aggregate stability [53]. In this context, studies conclude that wastewater irrigation modifies the physicochemical properties of the soil leading to a higher concentration of heavy metals in the soil, and consequently in plants [54]. On the other hand, the impact of wastewater

effluent on soil chemistry may be dramatic, since it decreases the concentrations of sulphates, nitrates, phosphorus, potassium, and changes in exchangeable cations [55]. Various studies show that the application of wastewater has increased soil salinity, organic matter and exchangeable elements like Na, K, Ca, and Mg. Furthermore, heavy metals accumulate in top soil [56]. Accordingly, proper management of wastewater irrigation and periodic monitoring of soil and plant quality parameters are crucial to ensure successful, safe, and long-term wastewater irrigation [57]. Based on that, efficient use of organic wastes in agriculture has to maintain soil fertility, in particular the biological properties of the soil [58]. The strict protection measures, stringent guidelines and an integrated system for the treatment and recycling of wastewater are needed to minimize the negative impacts of wastewater irrigation [59].

2 Experiment

2.1 Site Selection and Location

The selected site in Wadi AlSamin was the part where the flow of stream wastewater has been stopped since 2004. This site is divided in to two plots according to land use system. The first plot is the completely polluted soil by wastewater, where soil is abandoned by farmers and still uncultivated. The second plot is the mixed polluted soil. In this plot and during the construction of transfer pipe line, the deep soil was mixed with the upper and surrounding soil. This part is partially cultivated by farmers.

The study field (1015 m^2) was protected by fencing to prevent any damage or interference (figure 2).

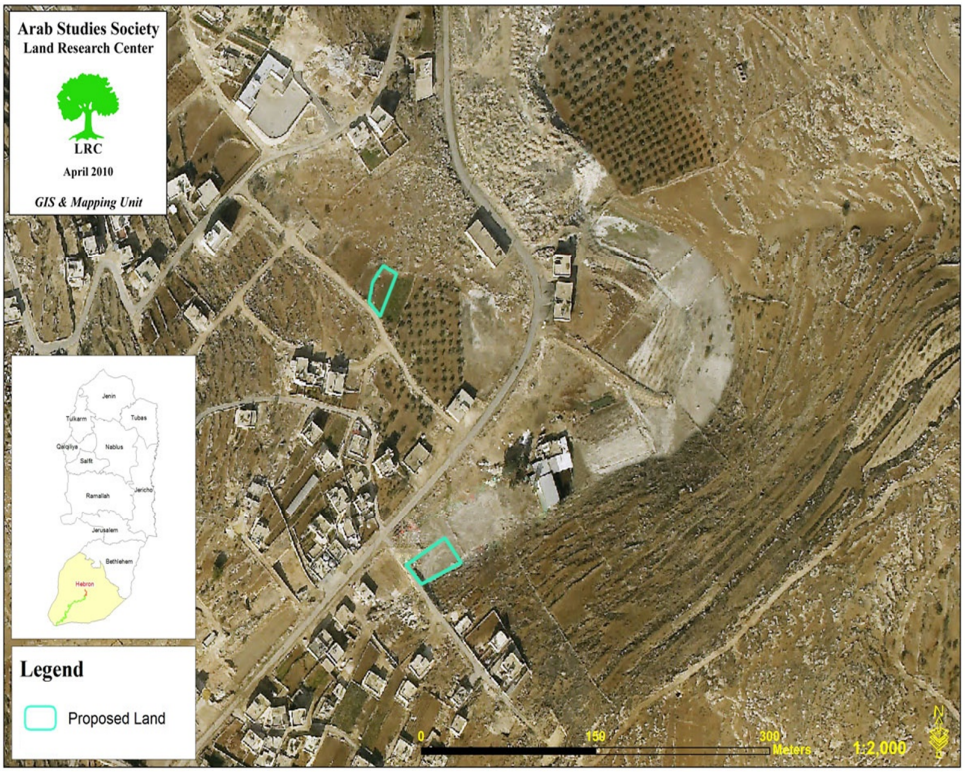


Figure 2 : Study location in Wadi Alsamin – Hebron

Source: Land Research Center - LRC, GIS and Mapping Unit,2012

2.2 Plant Material

Two local plant species (corn and tobacco) were selected for this study, since farmers used to cultivate these plant species at commercial scale. Tobacco plants are cultivated for cigarette production and corn for animal feeding. The growing beds were prepared in which three seeds of corn were planted at each spot and thinned after germination to one plant with planting density of 11 seedlings per m^2.Tobacco seeds were sown in cultivation plates then seedlings were transplanted to mini-pots in the study field with one seedling per spot; the planting density was 11 seedlings per m^2.

2.3 Experiment Layout

The allocated area was divided into 4 levels, each including three blocks, and each block including two main plots, one for tobacco and the other for corn. The area of each plot was 9 m^2, with buffer distance of 0.5 m between plots and 0.7 m between blocks. The experiment design used was factorial design. The experiment layout is shown in figure 3. There were 3 replicates for each treatment, with a total of 24 plots.

2.4 Statistical Analysis

Statistical tests were done using SPSS software-15.0. The soil-plant data were analyzed by analysis of variance (ANOVA). They were evaluated at a 95.0 % confident level with Scheffe analysis. The comparison between the concentrations of heavy metals was the dependent factor and the four plant parts as the independent factor (Annexes).

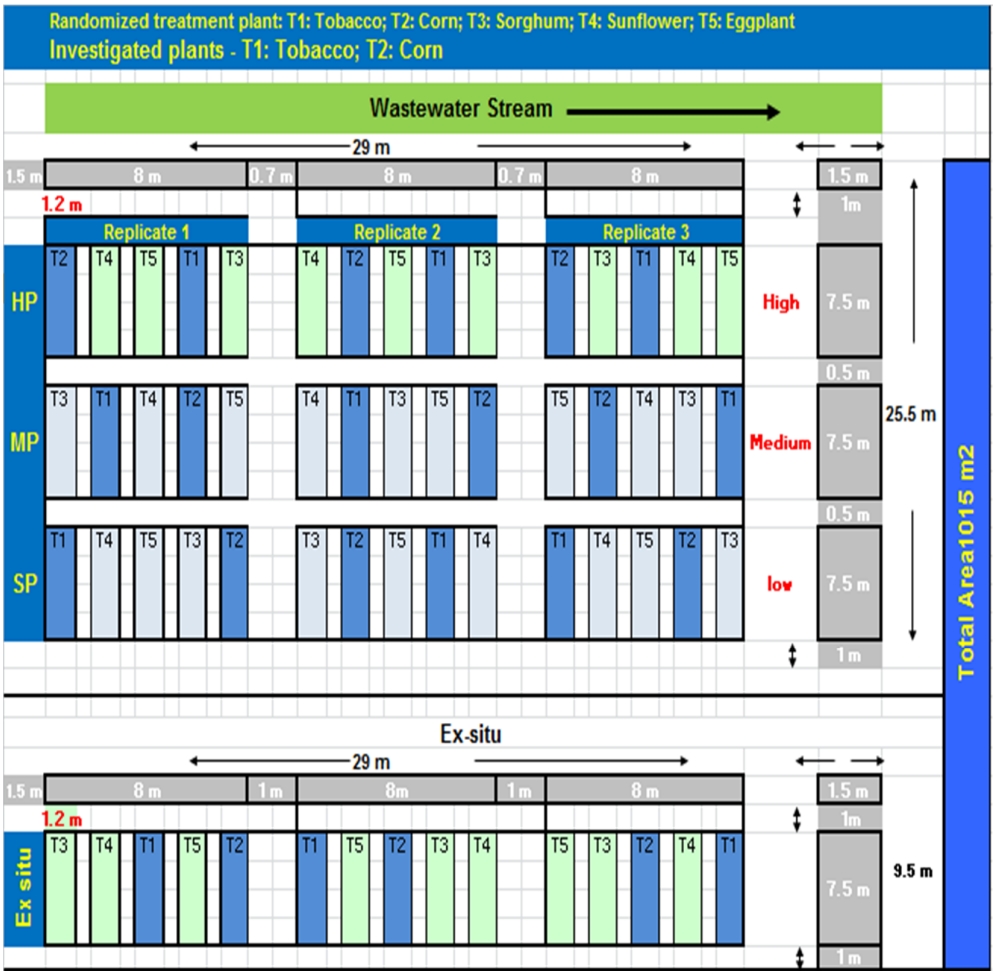


Figure 3: Experiment Layout

3 Treatments and Sample Collection

3.1 Soil Sampling

Before planting soil samples were collected from each block, in which one representative sample was collected from 5 soil spots. All samples were collected from the top soil (the first 30 cm). Samples were air-dried and stored in plastic bags. After planting, representative soil samples were prepared from the top soil (the rooting zone) and processed in similar way as pre-planting samples.

3.2 Plant Sampling

At the end of the growing season, plant samples were collected, and four parts of the plants were analyzed. These parts were roots, leaves, stems and fruits. A representative sample for each part was prepared from three plants per each plot. Moreover, the number of leaves was counted and the three middle leaves were collected for analysis. Stem samples were collected at 20 cm height from soil surface.

4 Parameters

Soil and plant parameters were assessed to evaluate and monitor plant performance in polluted soils. Soil parameters include heavy metals content, pH and EC. Plant parameters include plant height, leaf area index, biomass, and heavy metals content of roots, leaves, stems and fruits.

4.1 Soil Parameter

4.1.1 Heavy Metals

A full description of soil profile in the study area was done to determine which heavy metals are needed for analysis. Out of eight heavy metals (Cr, Zn, Cd, As, Pb, Co, Ni and Mn) that were analyzed in the study area, five metals were detected (Cr, Zn, Ni, Pb and Mn) and three of the detected metals were investigated in target plants as seen in figures 12, 13, 14.

The representative soil samples were dried in an oven at 70 C^{o} for 3-4 hours and then sieved down to 0.2 mm in diameter. Soils were analyzed with inductive coupled plasma (ICP) against multi-element standard. After that the soil were ignited at 550-600 C^{o} for 4.5 - 5 hours then cooled in desiccators at room temperature. The digest ash content was mixed directly with concentrated nitric acid and hydrochloric acid for a minimum of 3-4 hours until solution is clear. Finally, the clear solutions were filtered through (Wattman # 1,) and then diluted with distilled water to the required volume and analyzed by ICP.

4.1.2 Soil pH

Soil pH was measured using electronic pH meter (827. pH Lab, Metrohm). Figure 4 shows the mean pH for each level. Soil pH was measured using 1:5 $w.v^{-1}$ soil extracts. These extracts were then measured to obtain the pH of the samples in the pilot area.

4.1.3 Soil Electrical Conductivity (EC)

EC was measured using the conductivity meter (4010 Jenway). Figure 5 shows the mean of EC for each level. Soil salinities were measured using 1:5 $w.v^{-1}$ soil extracts. These extracts were then measured to obtain the electrical conductivity of the samples in the pilot area.

4.2 Plant Parameters

4.2.1 Plant Height

The mean of plant height for each replicate was taken from five plants that were selected randomly as shown in figure 6 and 7. The readings were measured every two weeks for all replicates.

4.2.2 Leaf Area Index (LAI)

The leaf area was measured by using LAI -2000- USA. The area of middle leaves for three plants per each replicate was taken and the total leaf area was calculated as shown in figure 10, 11.

4.2.3 Biomass

Biomass was measured from five plants that were taken randomly from each replicate. Drying was done in the field and the results are shown in figure 8, 9.

4.2.4 Heavy Metals

The investigated heavy metals that were detected in soil were investigated also in plants. Figures of 15-38 of corn and tobacco plant show the extractable heavy metals through all plant parts. The representative plant samples were analyzed with ICP against multi-element standard which were dried in an oven at 70 C^o for 3-4 hours and then the plant were cut with scissors followed by mechanical processer to a length of (1 - 2 mm). After that plant ignited at 550-600 C^o for 4.5 - 5 hours then cooled in desiccators to room temperature. The digest ash content was mixed directly with concentrated nitric acid and hydrochloric acid for a minimum of 3-4 hours until solution is clear. Finally, the clear solutions were filtered through (Wattman # 1,) and then diluted with distilled water to the required volume and analyzed by ICP.

5 Results

5.1 Soil pH

Soil pH in polluted soil differs from that in untreated soil. The value of pH ranges from 7.3 to 7.8, with mean of 7.5 in polluted soil and 7.2 in untreated part. Results show significant differences between untreated parts (Ex-situ) with highly moderate level (HP) (Figure 4).

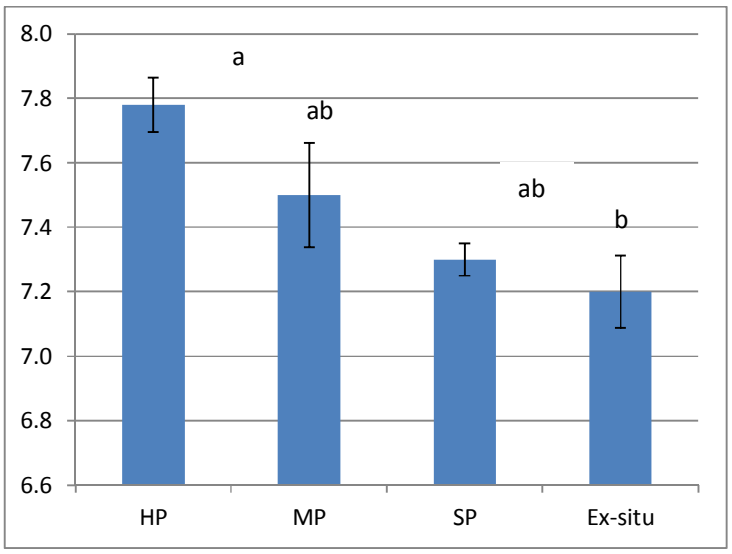


Figure 4: Soil pH variation before planting

- HP: High pollution; MP: Medium pollution; SP: Slight pollution; Ex-situ: reference plot.
- Values with the same letter for each element are statically not different according to sheffe's test " $P<0.05$"

Figure 5 shows the influence of pollution level after planting on soil pH where the pH with corn plant in polluted soil varied from 7.4 to 7.6 with mean of 7.5while in untreated soil was 7.2 with insignificant differences with polluted part. Regarding

tobacco plots the pH value was 7.7 in polluted part and 7.3 in untreated part with insignificant differences.

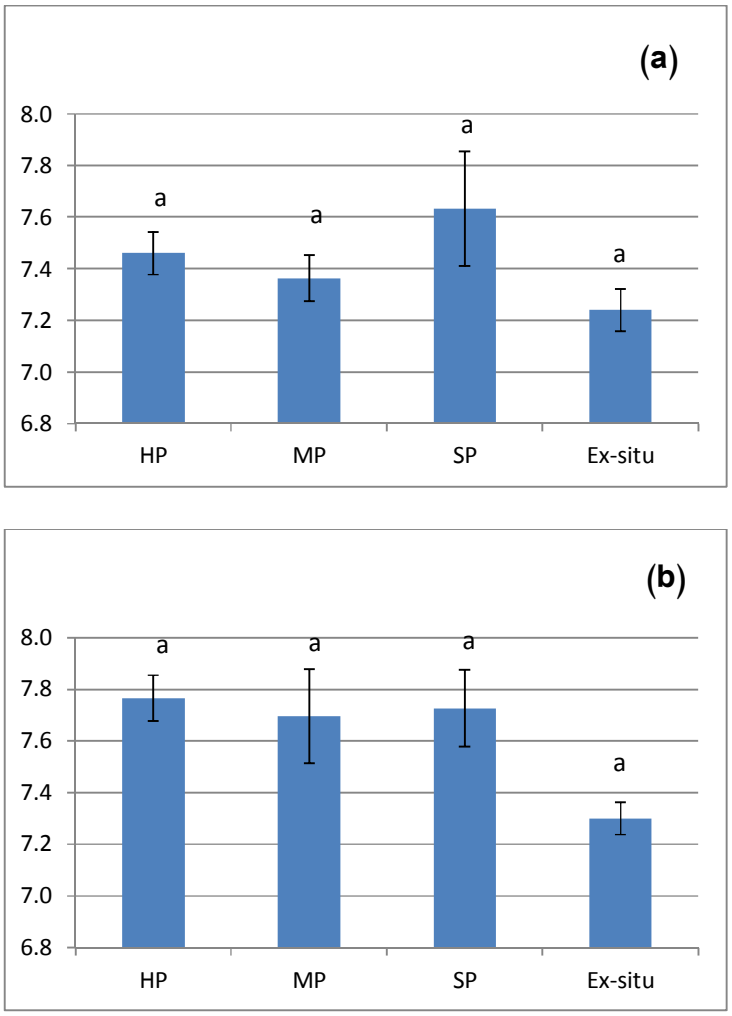


Figure 5: Influence of pollution level after planting on the soil pH

(a):for corn ; (b): for tobacco plant .

- HP: High pollution; MP: Medium pollution; SP: Slight pollution; Ex-situ: reference plot.
- Values with the same letter for each element are statically not different according to sheffe's test " $P<0.05$"

5.2 Soil Electrical Conductivity (EC)

The soil EC value in-situ ranged from 0.30-0.37 ds.m^{-1}and it was 0.37 dS.m^{-1} in ex-situ plot as shown in figure 5.There was no considerable difference between polluted and untreated soil in the study area.

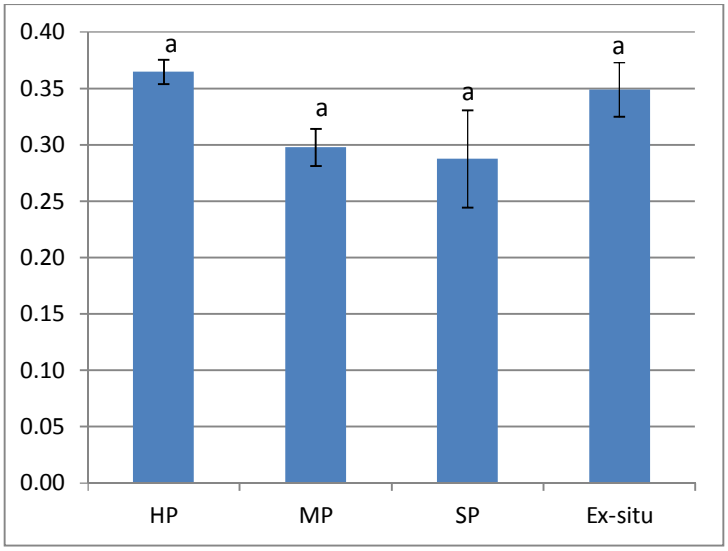


Figure 6: Influence of pollution level before planting on the soil Ec (ds.m^{-1})

- HP: High pollution; MP: Medium pollution; SP: Slight pollution; Ex-situ: reference plot.
- Values with the same letter for each element are statically not different according to sheffe's test " P<0.05"

Figure 7 shows the influence of pollution level on EC after planting where the EC value for both plants, either for polluted or untreated part, was 0.2 ds.m^{-1}with non-significant differences between the two parts of soil in the study area.

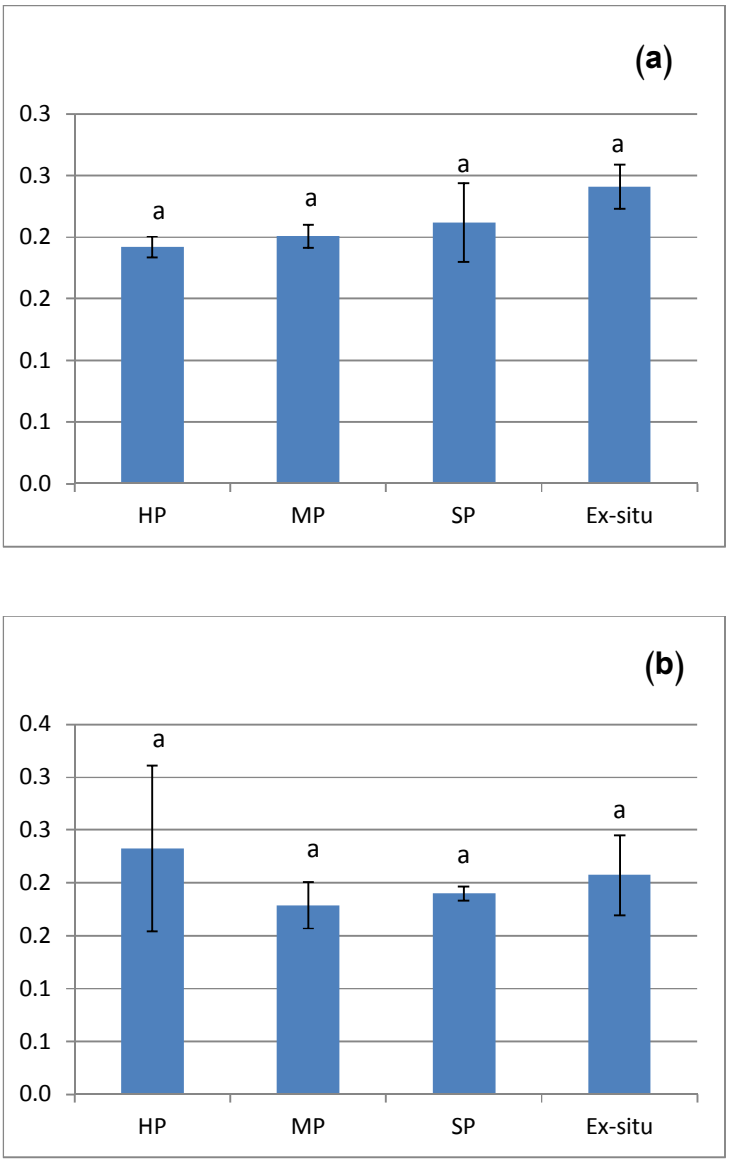


Figure 7: Influence of pollution level after planting corn & tobacco on the soil Ec. (a): for corn plant; (b): for tobacco plant. ($ds.m^{-1}$)

- HP: High pollution; MP: Medium pollution; SP: Slight pollution; Ex-situ: reference plot.
- Values with the same letter for each element are statically not different according to sheffe's test " $P<0.05$"

5.3 Plant Height

The plant height for the plants grown in polluted plots was significantly different than for the plants grown in unpolluted plot. In corn plants the height range from 1.28 to 1.38 m with mean of 1.3 m in polluted part and 2.1 m in Ex-situ, while the height of tobacco range from 0.33 to 0.37 m with mean of 0.35 m in polluted part compared to 0.49 m in untreated part as seen in figure 8, 9.

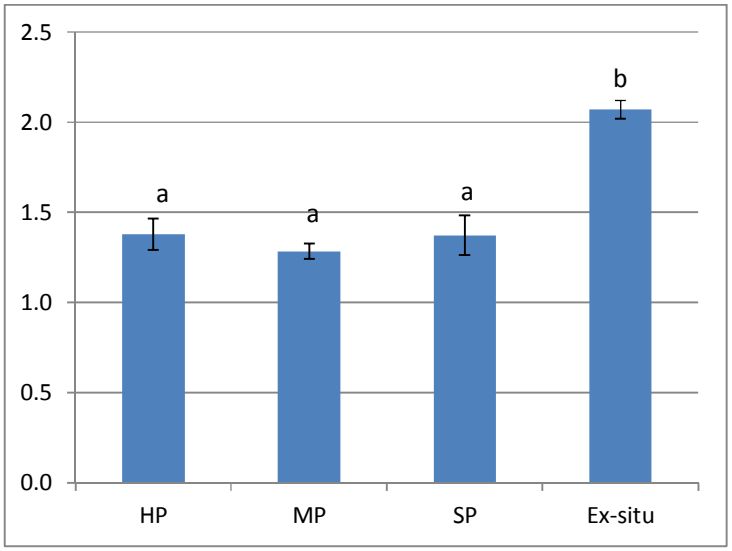


Figure 8: Height of corn plant (m)

- HP: High pollution; MP: Medium pollution; SP: Slight pollution; Ex-situ: reference plot.
- Values with the same letter for each element are statically not different according to sheffe's test " P<0.05"

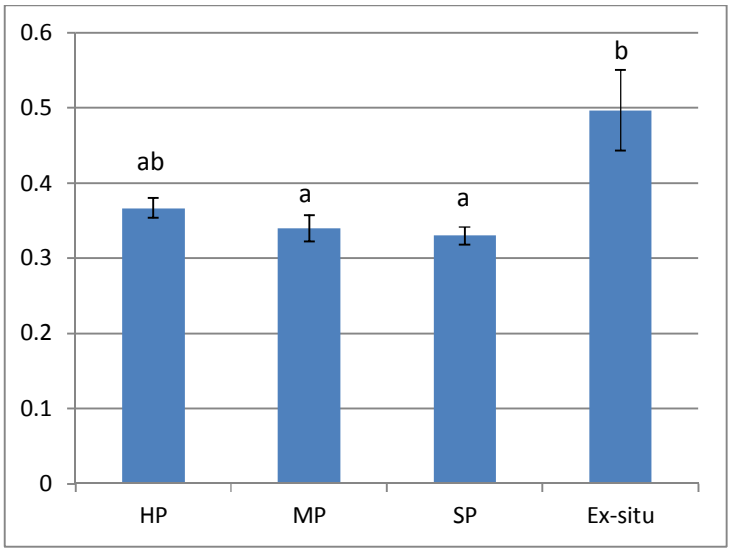


Figure 9: Height of tobacco plant (m)

- HP: High pollution; MP: Medium pollution; SP: Slight pollution; Ex-situ: reference plot.
- Values with the same letter for each element are statically not different according to sheffe's test " $P<0.05$"

5.4 Plant Biomass

The dry weight value of corn plants ranged from 0.05 to 0.1 kg.seedling^{-1} and from 0.01 to 0.03 kg.seedling^{-1} for tobacco (figures 10 and 11). The difference was significant between polluted and untreated soil for both plants.

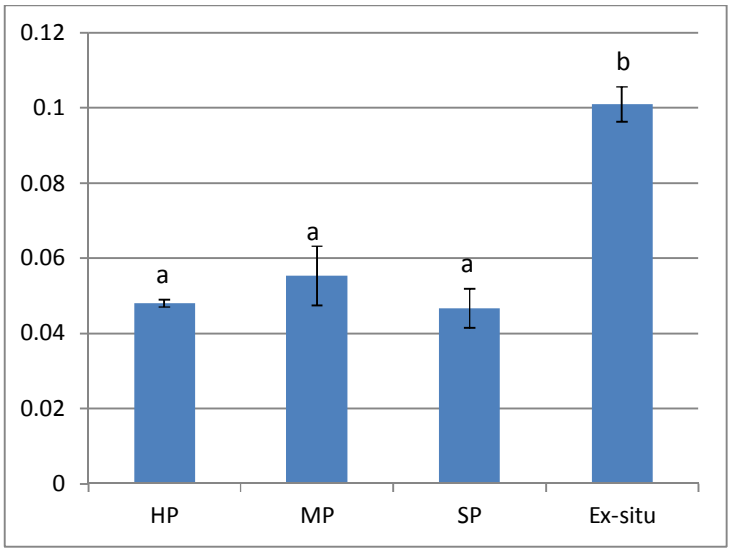


Figure 10: Corn dry weight (kg)

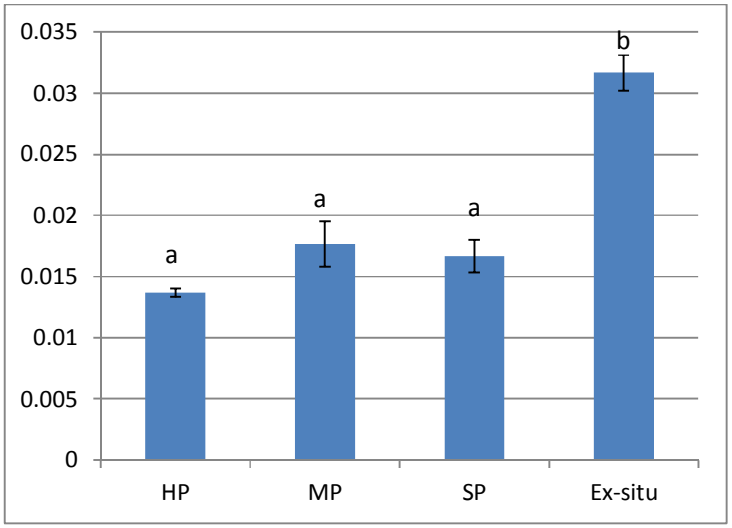


Figure 11: Tobacco dry weight (kg)

- HP: High pollution; MP: Medium pollution; SP: Slight pollution; Ex-situ: reference plot.
- Values with the same letter for each element are statically not different according to sheffe's test " $P<0.05$"

5.5 Leaf Area Index (LAI)

LAI of corn ranges from 7.5-8.5 and for tobacco plant from 1.0 -2.1 as shown in figure 12 and 13. There were insignificant differences for both plants in LAI between polluted and untreated soil.

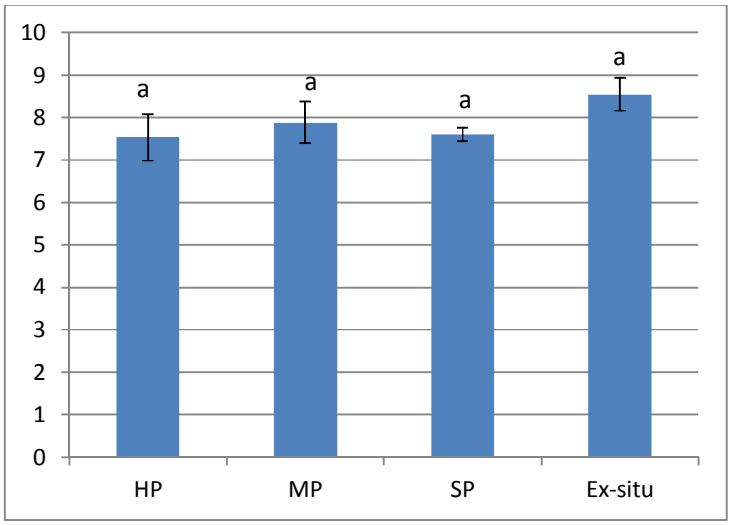


Figure 12: Leaf area index (LAI) of corn

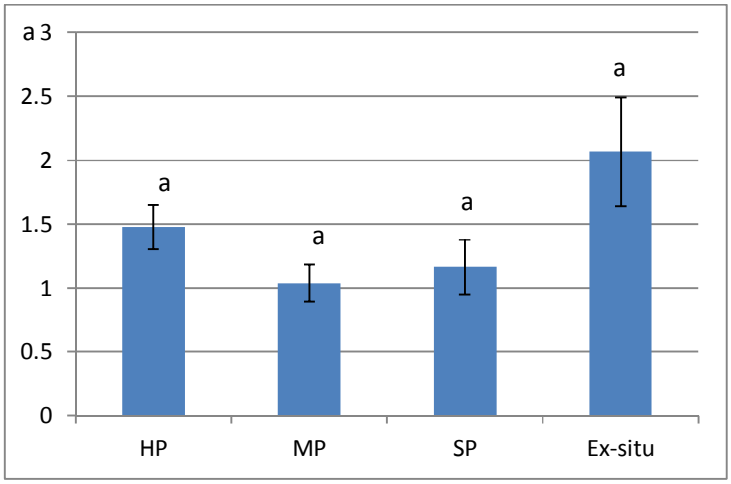


Figure 13: Leaf area index (LAI) of tobacco

- HP: High pollution; MP: Medium pollution; SP: Slight pollution; Ex-situ:: reference plot.
- Values with the same letter for each element are statically not different according to sheffe's test " $P<0.05$"

5.6 Heavy Metals Content in Soil before Planting

Soil survey was conducted for 8 heavy metals in the experiment site. From the eight analyzed heavy metals (Cd, Co, B, Cr, Mn, Zn, Ni, Pb), five were detected, namely Cr, Mn, Zn, Ni and Pb. For our experiment, Cr, Zn and Mn were investigated and the results are show in figures of 14, 15, and 16.

The content of chromium in polluted soil varied from 121.3 - 173.7 $mg.kg^{-1}$. The mean of the content of this element is 147 $mg.kg^{-1}$ and its content in untreated soil is 101.3 $mg.kg^{-1}$. The difference was insignificant between polluted and untreated soil as seen in figure 14.

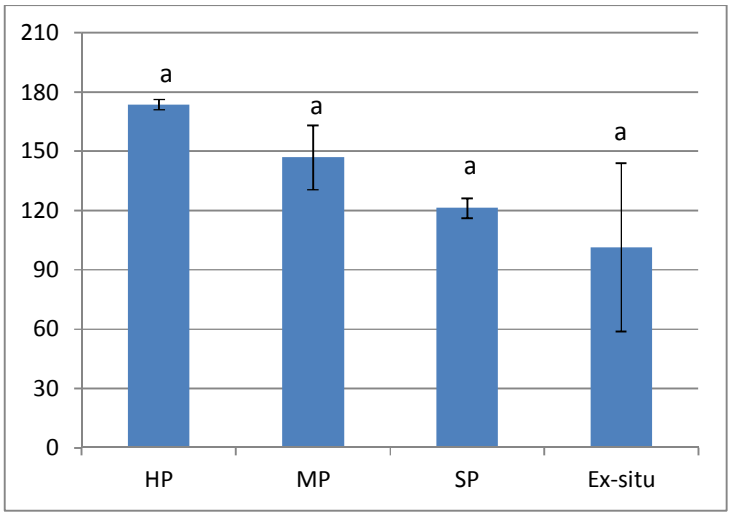


Figure 14: Cr concentration in soil before planting ($mg.kg^{-1}$)

- HP: High pollution; MP: Medium pollution; SP: Slight pollution; Ex-situ: reference plot.
- Values with the same letter for each element are statically not different according to sheffe's test " $P<0.05$"

The content of manganese in polluted soil varied from 44.3 -53.3 mg.kg^{-1} with mean of the content of 48.8 mg.kg^{-1} where its content in untreated soil is 532 mg.kg^{-1}. Figure 15 shows the significant differences between polluted part and untreated part.

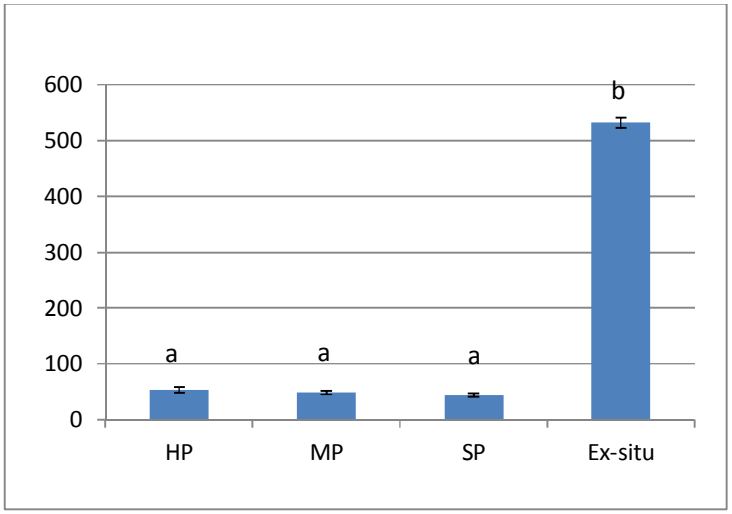


Figure 15: Mn concentration in soil before planting (mg.kg^{-1})

- HP: High pollution; MP: Medium pollution; SP: Slight pollution; Ex-situ: reference plot.
- Values with the same letter for each element are statically not different according to sheffe's test " P<0.05"

The zinc metal was detected only in highly polluted level (HP) in the nearest point to the wastewater stream with concentration of 68 mg.kg^{-1} where it was not detected in moderate (MP) and slightly level (SP). Zinc content in untreated soil was 86 mg.kg^{-1}. However, the differences in Zn content between levels were insignificant.

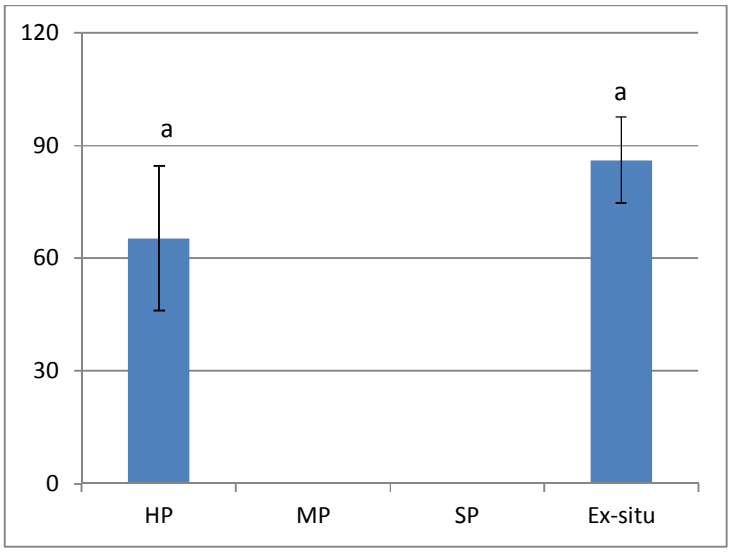


Figure 16: Zn concentration in soil before planting (mg.kg^{-1})

- HP: High pollution; MP: Medium pollution; SP: Slight pollution; Ex-situ: reference plot.
- Values with the same letter for each element are statically not different according to sheffe's test " P<0.05"

5.7 Heavy Metals Content in Soil after Planting

In this section only the chromium metal concentration in soil after planting is illustrated where it is considered as a pollutant metal among the other investigated metals (Mn , Zn). Figure 17 shows the chromium variation in corn plots. Its value varies from 124 - 169 mg.kg^{-1} in polluted soil with mean of 140 mg.kg^{-1} and 79 mg.kg^{-1} in untreated part with significant difference between highly polluted (HP) and untreated part (Ex-situ) (figure 17). While in tobacco plots, the chromium varied from 119 - 154 mg.kg^{-1} in polluted soil with mean of 134 mg.kg^{-1} and 82 mg.kg^{-1} in untreated part in which the difference was significant between polluted soil mainly highly(HP) and medium polluted (MP) with untreated soil.(Figure 18).

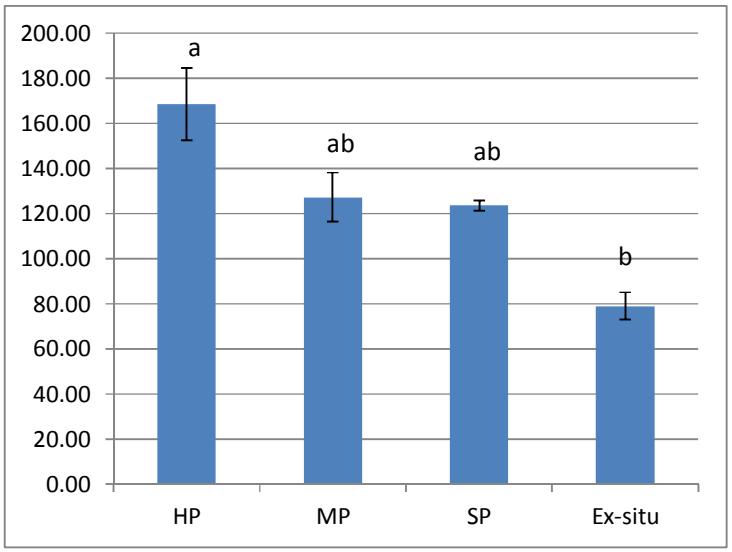


Figure 17: Cr concentration in soil after planting with corn (mg.kg^{-1})

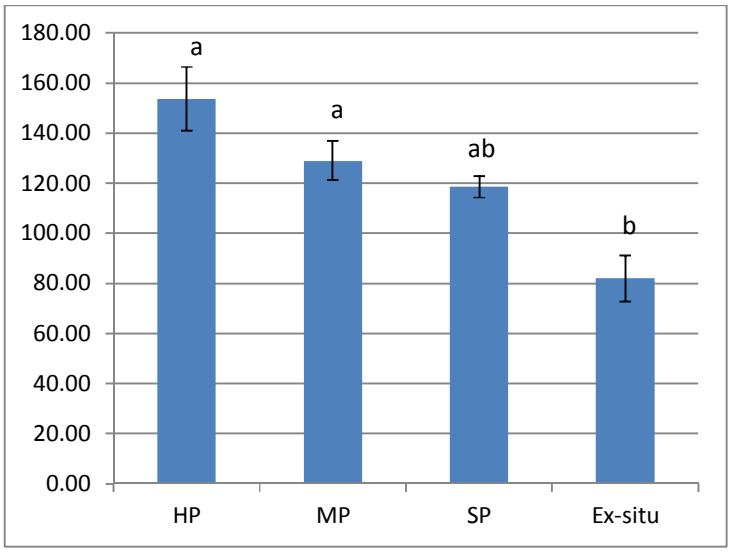


Figure 18: Cr variation in soil after planting with tobacco (mg.kg^{-1})

- HP: High pollution; MP: Medium pollution; SP: Slight pollution; Ex-situ: reference plot.
- Values with the same letter for each element are statically not different according to sheffe's test " $P<0.05$"

5.8 Heavy Metals Content in Plant

The content of Cr, Mn and Zn through all plant axis of corn and tobacco plant was measured. The contents of metals were examined in the above ground plant parts (roots, stems, leaves and fruits). The lowest metal concentration was observed in the fruit, higher in the stem and highest in the leaf. This is the state of Cr and Mn for both plants. Zn content in corn plant was highest in stem.

5.8.1 Heavy Metals Content in Whole Corn Plant:

The chromium content in whole corn plant varied from 2.2 to 8.1 $mg.kg^{-1}$ in polluted part, with mean content of 5.5 $mg.kg^{-1}$ while in untreated part the chromium content was 6.0 $mg.kg^{-1}$. The difference was not significant between polluted soil and untreated part (figure 19).

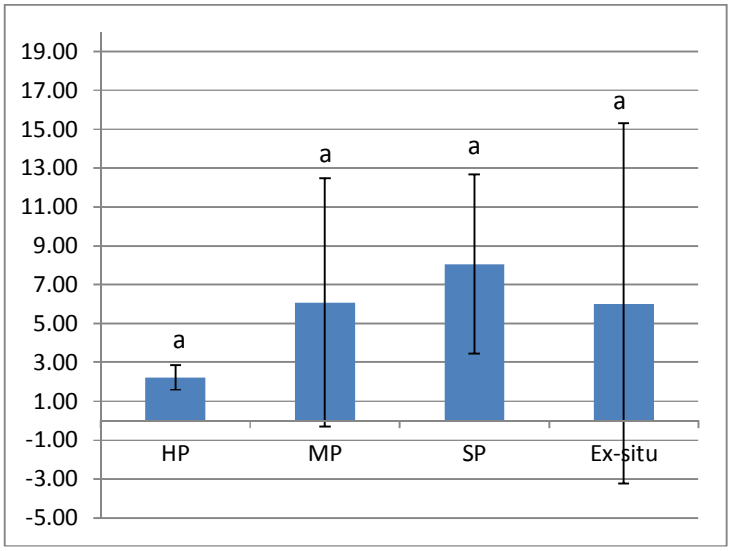


Figure 19: Cr content in vegetative above ground parts of corn ($mg.kg^{-1}$)

- HP: High pollution; MP: Medium pollution; SP: Slight pollution; Ex-situ: reference plot.
- Values with the same letter for each element are statically not different according to sheffe's test " $P<0.05$"

The content of manganese in whole corn plant varied from 5.0 to 5.3 mg.kg^{-1} with mean content of 15.6 mg.kg^{-1}while its content in untreated soil was 18.8 mg.kg^{-1}. Figure 20 exhibit the significant difference between polluted parts and Ex-situ.

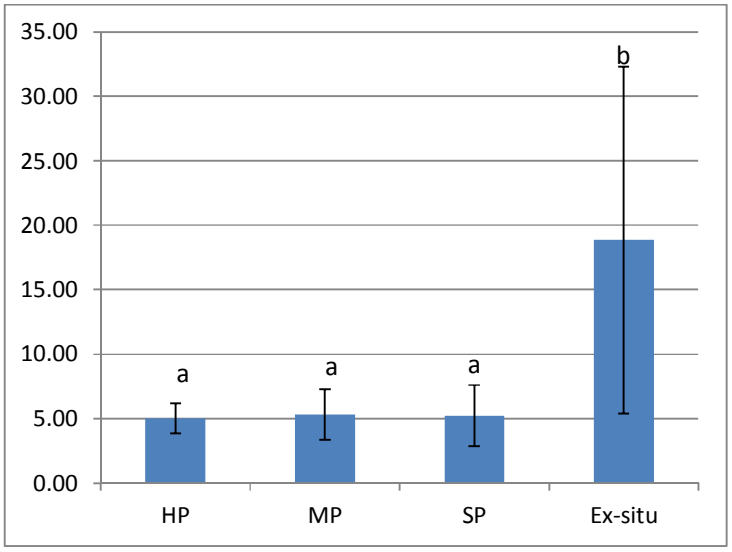


Figure 20: Mn content in vegetative above ground parts of corn (mg.kg^{-1})

- HP: High pollution; MP: Medium pollution; SP: Slight pollution; Ex-situ: reference plot.
- Values with the same letter for each element are statically not different according to sheffe's test " P<0.05"

Zinc metal was detected only in highly polluted level with 35.7 mg.kg^{-1}. The zinc in the untreated soil was 27.2 mg.kg^{-1}. Variations in Zinc concentration were statistically not different (figure 21).

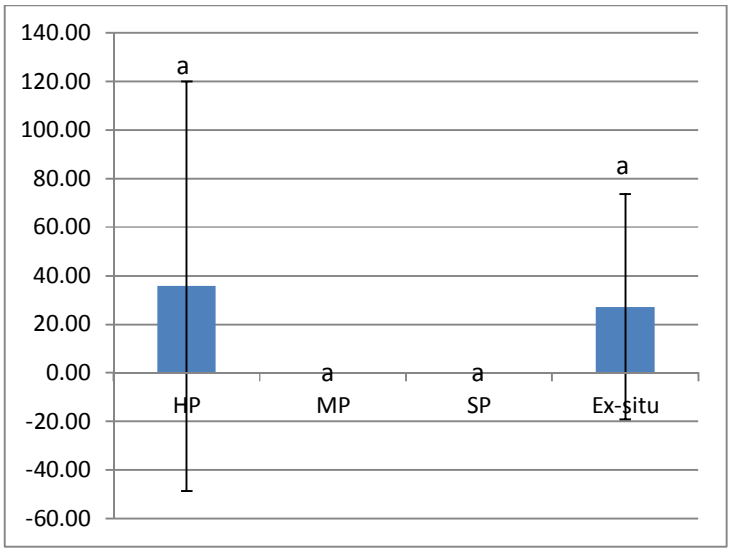


Figure 21: Zn content in vegetative above ground parts of corn (mg.kg^{-1})

- HP: High pollution; MP: Medium pollution; SP: Slight pollution; Ex-situ: reference plot.
- Values with the same letter for each element are statically not different according to sheffe's test " $P<0.05$"

5.8.2 Heavy Metals Content in Corn Plant Parts

The order of heavy metal content in corn plant parts for Cr and Mn metals were as Leaves > stems> roots > fruit while for Zn metal the order was as stems> leaves> roots > fruit.

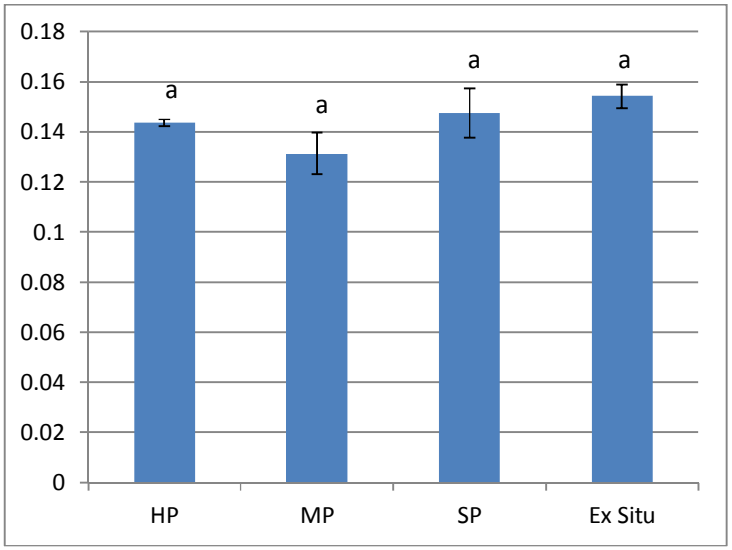


Figure 22: Cr distribution in corn roots (mg.kg^{-1})

- HP: High pollution; MP: Medium pollution; SP: Slight pollution; Ex-situ: reference plot.
- Values with the same letter for each element are statically not different according to sheffe's test " P<0.05"

Figure 22 shows the Cr content in roots of corn. The content varied from 0.13 to 0.15 mg.kg^{-1}. Statistically the difference was insignificant between in-situ and ex-situ.

Figure 23, 24 and 25 shows the Cr contetn in the vegetative above ground parts of stems, leaves and fruit. The Cr content in these parts was 3.13 - 7.80, 3.47 - 16.2 and 0.02 - 0.14 mg.kg^{-1} respectively. The different was significantly between

polluted and untreated only in fruit organ even through levels in polluted part as seen in figure 25 while differences were not significant for stems and leaves.

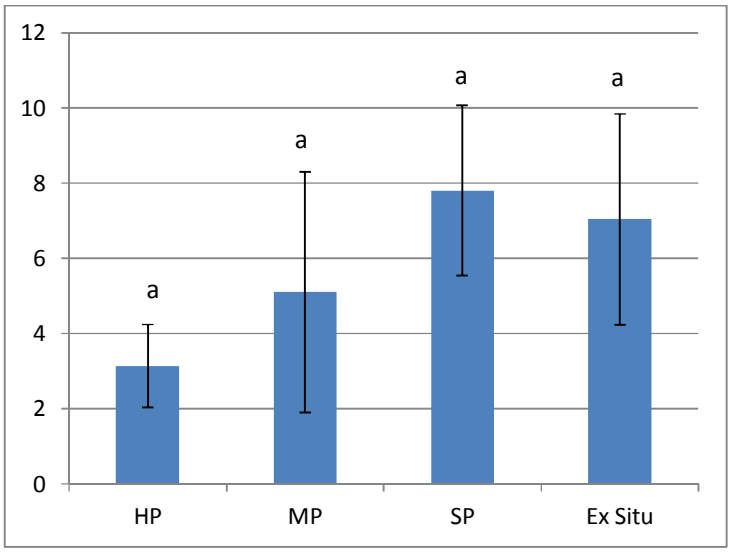


Figure 23: Cr distribution in corn stems (mg.kg^{-1})

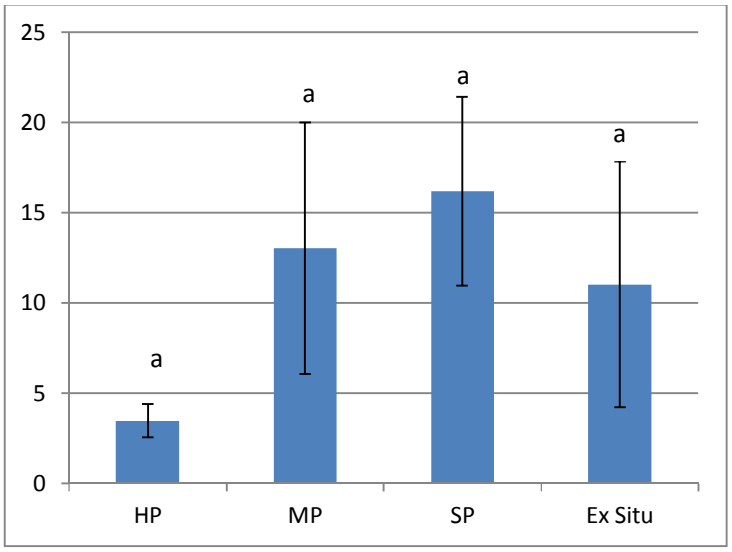


Figure 24: Cr distribution in corn leaves (mg.kg^{-1})

- HP: High pollution; MP: Medium pollution; SP: Slight pollution; Ex-situ: reference plot.
- Values with the same letter for each element are statically not different according to sheffe's test " $P<0.05$"

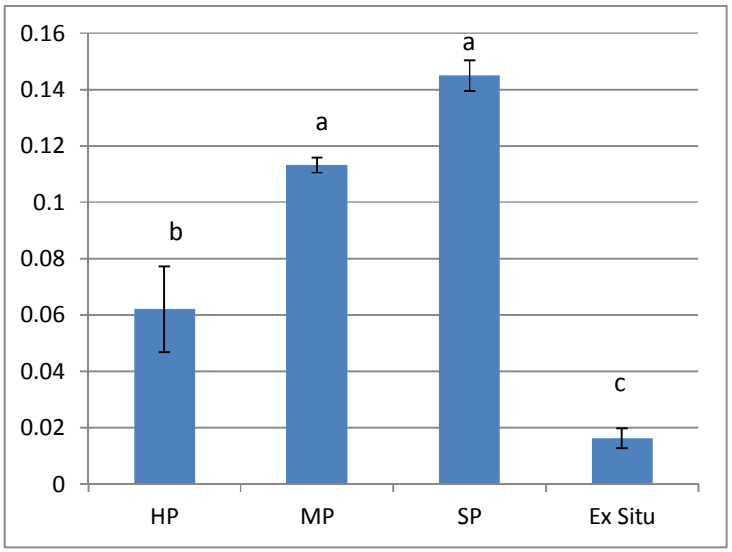


Figure 25: Cr distribution in corn fruits (mg.kg^{-1})

- HP: High pollution; MP: Medium pollution; SP: Slight pollution; Ex-situ: reference plot.
- Values with the same letter for each element are statically not different according to sheffe's test " P<0.05"

The Mn content in roots, stems, leaves and fruits, were 0.01 - 0.05, 2.77 - 13.8, 9.63 - 42.73 and 0.01 mg.kg^{-1} respectively. The differences were significant only in roots between polluted with untreated and insignificant in other plant parts. (Figure 26, 27, 28, and 29).

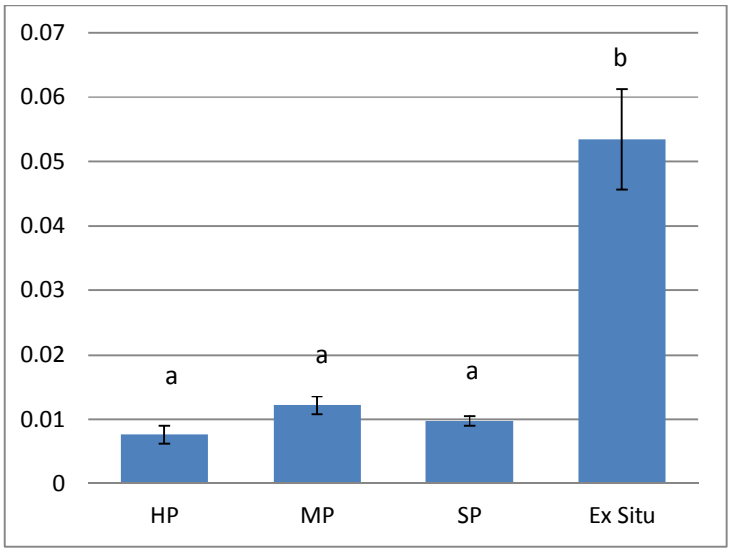


Figure 26: Mn distribution in corn roots (mg.kg^{-1})

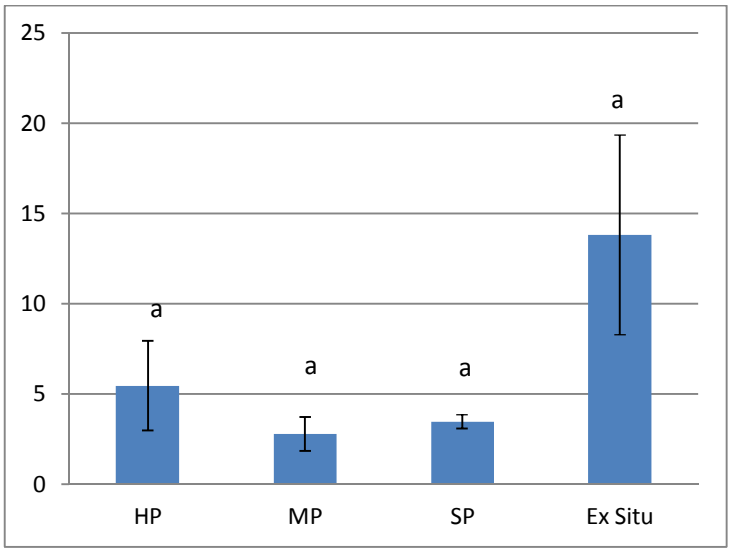


Figure 27: Mn distribution in corn stems (mg.kg^{-1}).

- HP: High pollution; MP: Medium pollution; SP: Slight pollution; Ex-situ: reference plot.
- Values with the same letter for each element are statically not different according to sheffe's test " P<0.05"

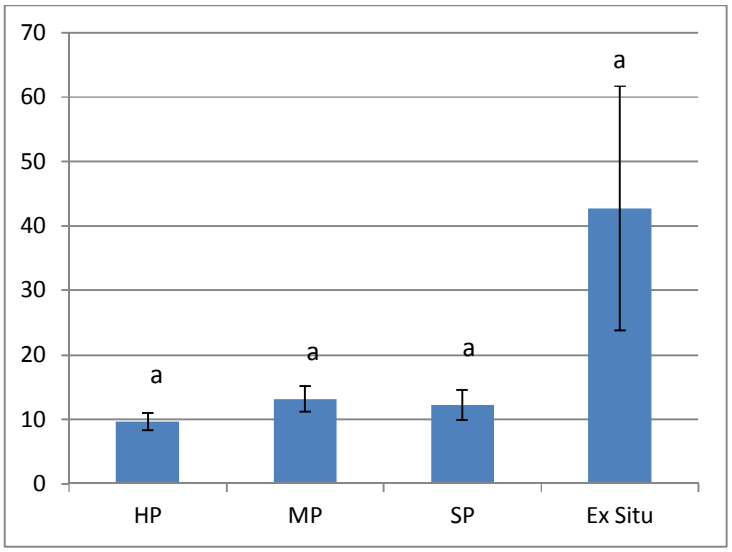


Figure 28: Mn distribution in corn leaves (mg.kg^{-1})

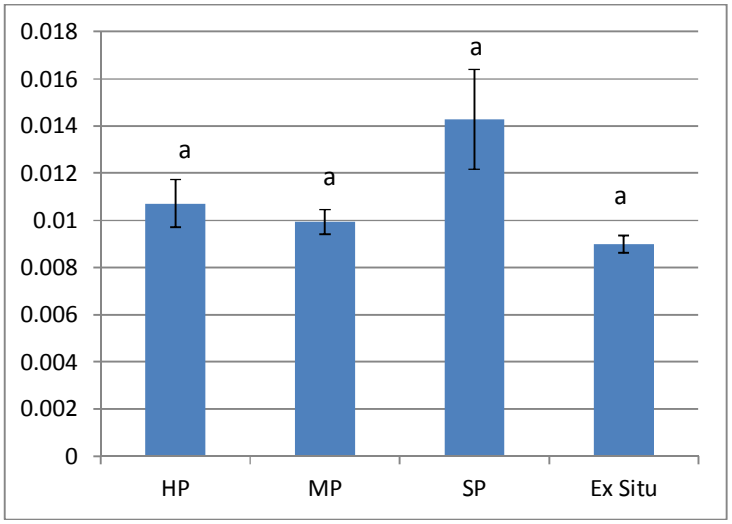


Figure 29: Mn distribution in corn fruits (mg.kg^{-1})

- HP: High pollution; MP: Medium pollution; SP: Slight pollution; Ex-situ: reference plot.
- Values with the same letter for each element are statically not different according to sheffe's test " P<0.05"

Figure 30, 31, 32 and 33 illustrate the zinc content in roots, stems, leaves and fruits of corn plant. Zinc metal was detected only in highly polluted level (HP) with content of 0.17, 75.4, 31.6, and 0.12 $mg.kg^{-1}$ for roots, stems, leaves and fruits respectively and in untreated soil with content of 0.12, 59.9, 21.5 and 0.06 $mg.kg^{-1}$ in roots, stems, leaves and fruit respectively. The differences were significant only in fruit organ between polluted soil and reference plot.

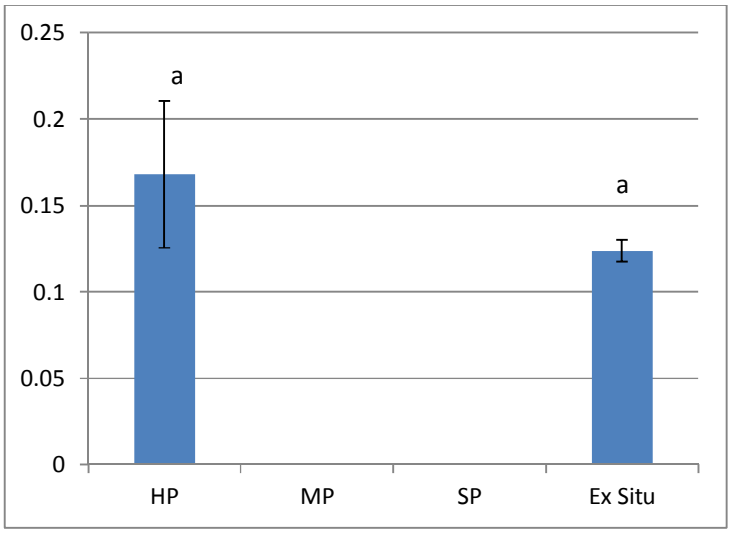


Figure 30: Zn distribution in corn roots ($mg.kg^{-1}$)

- HP: High pollution; MP: Medium pollution; SP: Slight pollution; Ex-situ: reference plot.
- Values with the same letter for each element are statically not different according to sheffe's test " $P<0.05$"

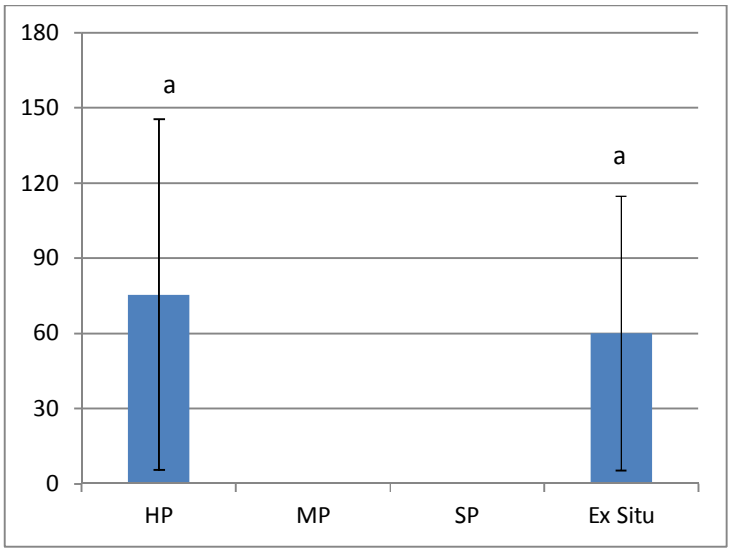


Figure 31: Zn distribution in corm stems (mg.kg^{-1})

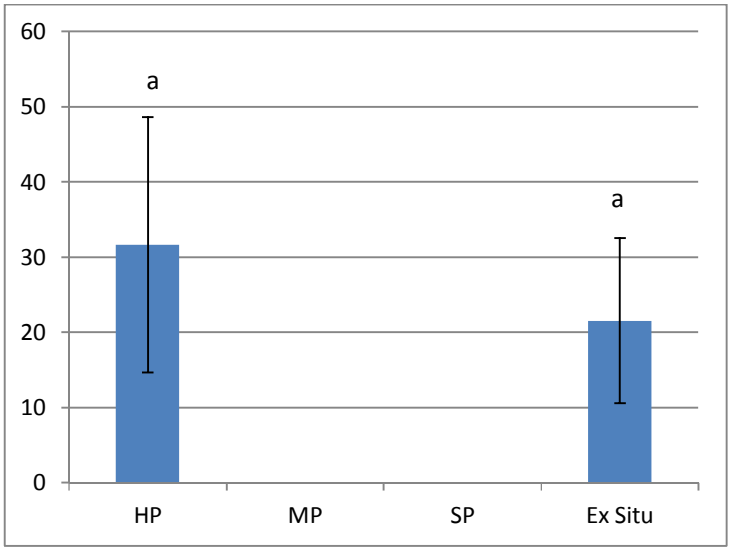


Figure 32: Zn distribution in corn leaves (mg.kg^{-1})

- HP: High pollution; MP: Medium pollution; SP: Slight pollution; Ex-situ: reference plot.
- Values with the same letter for each element are statically not different according to sheffe's test " $P<0.05$"

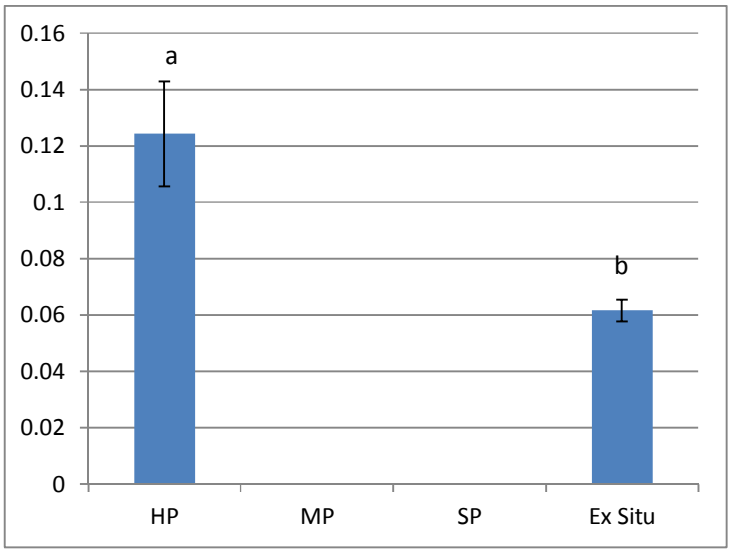


Figure 33: Zn distribution in corn fruits (mg.kg^{-1})

- HP: High pollution; MP: Medium pollution; SP: Slight pollution; Ex-situ: reference plot.
- Values with the same letter for each element are statically not different according to sheffe's test " $P<0.05$"

5.8.3 Heavy Metals Content in Whole Tobacco Plant

The content of chromium in tobacco plant varied from 1.6 to 2.0 $mg.kg^{-1}$ with mean content of 1.8 $mg.kg^{-1}$ in polluted soil while its content in untreated soil was 4.3 $mg.kg^{-1}$. Statistically the difference was not significant (Figure 34).

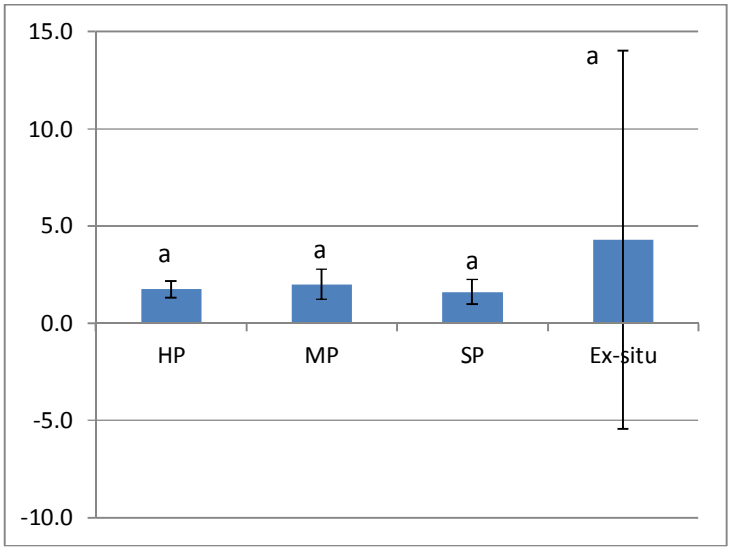


Figure 34: Cr content in vegetative above ground parts of tobacco ($mg.kg^{-1}$)

- HP: High pollution; MP: Medium pollution; SP: Slight pollution; Ex-situ: reference plot.
- Values with the same letter for each element are statically not different according to sheffe's test " $P<0.05$"

Figure 35 shows the manganese content in tobacco plant which ranged from 6.4 to 7.9 $mg.kg^{-1}$ with mean content of 7.2 $mg.kg^{-1}$ in polluted part. High content of manganese (30.4 $mg.kg^{-1}$) was observed in untreated part with significant differences related to the polluted parts.

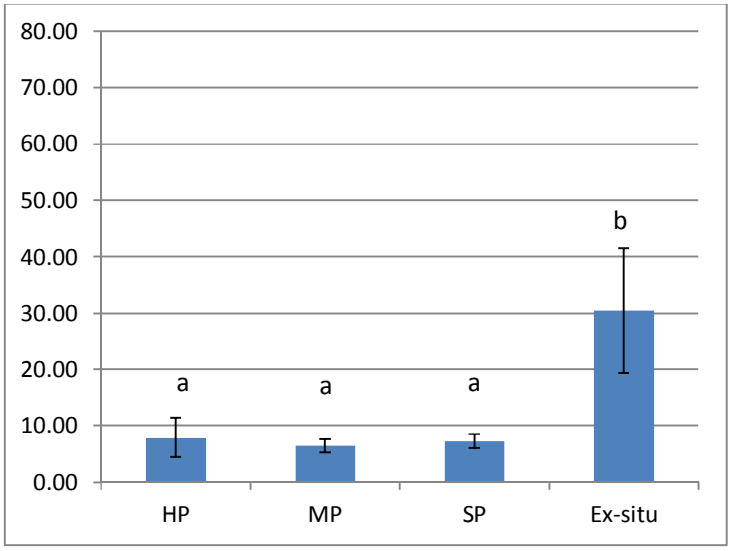


Figure 35: Mn content in vegetative above ground parts of tobacco ($mg.kg^{-1}$)

- HP: High pollution; MP: Medium pollution; SP: Slight pollution; Ex-situ: reference plot.
- Values with the same letter for each element are statically not different according to sheffe's test " $P<0.05$"

In tobacco plant, zinc was detected only in highly polluted soil with content of 35.7 $mg.kg^{-1}$ and 26.1 $mg.kg^{-1}$ in untreated soil but the difference was not significant (Figure 36).

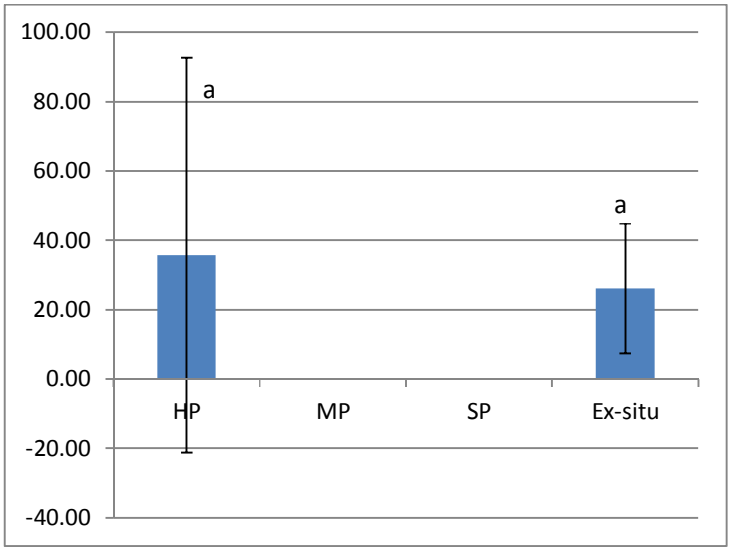


Figure 36: Zn content in vegetative above ground parts of tobacco ($mg.kg^{-1}$)

- HP: High pollution; MP: Medium pollution; SP: Slight pollution; Ex-situ: reference plot.
- Values with the same letter for each element are statically not different according to sheffe's test " $P<0.05$"

5.8.3.1 Heavy Metals Content in Tobacco Plant Parts

The order of Cr, Mn and Zn content in tobacco plant was as; leaves > stems> fruit > roots. The Cr content of roots in polluted soil was significantly different than that in untreated part mainly highly polluted (HP) and medium polluted (MP) (figure 37). It ranged from 0.07 to 0.09 $mg.kg^{-1}$ with mean of 0.08 $mg.kg^{-1}$ in polluted soil and 0.04 $mg.kg^{-1}$ in untreated part.

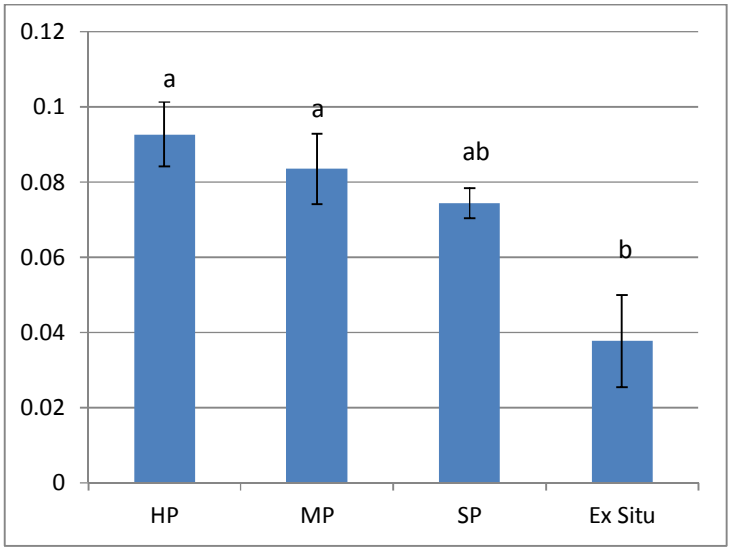


Figure 37: Cr distribution in tobacco roots ($mg.kg^{-1}$)

- HP: High pollution; MP: Medium pollution; SP: Slight pollution; Ex-situ: reference plot.
- Values with the same letter for each element are statically not different according to sheffe's test " $P<0.05$"

The chromium content in the vegetative parts of tobacco plant were as follows; 1.6 - 4.3 in stems, 3.0 - 8.4 $mg.kg^{-1}$ in leaves and 0.1 - 0.13 $mg.kg^{-1}$ fruits. These values exhibit no significant differences between polluted and untreated part as seen in figures of 38, 39 and 40.

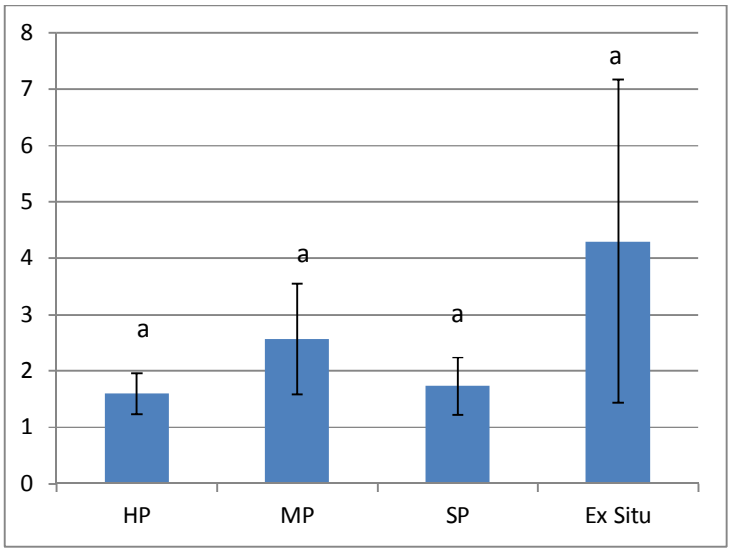


Figure 38: Cr distribution in tobacco stems (mg.kg^{-1})

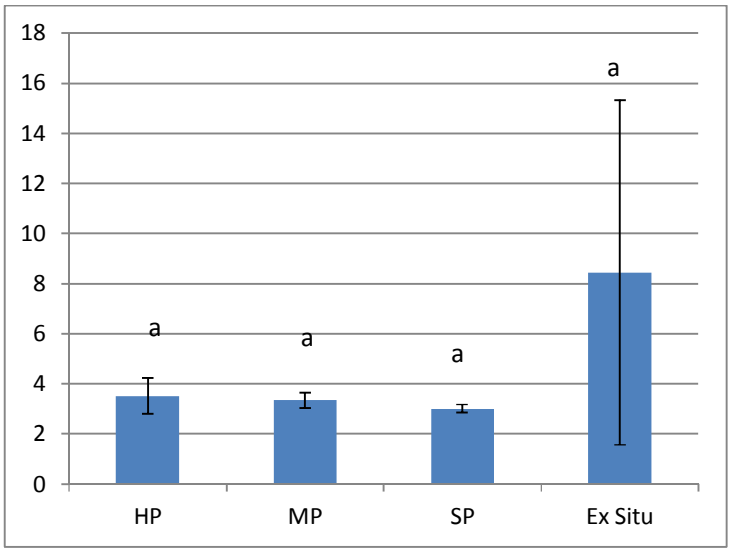


Figure 39: Cr distribution in tobacco leaves (mg.kg^{-1})

- HP: High pollution; MP: Medium pollution; SP: Slight pollution; Ex-situ: reference plot.
- Values with the same letter for each element are statically not different according to sheffe's test " $P<0.05$"

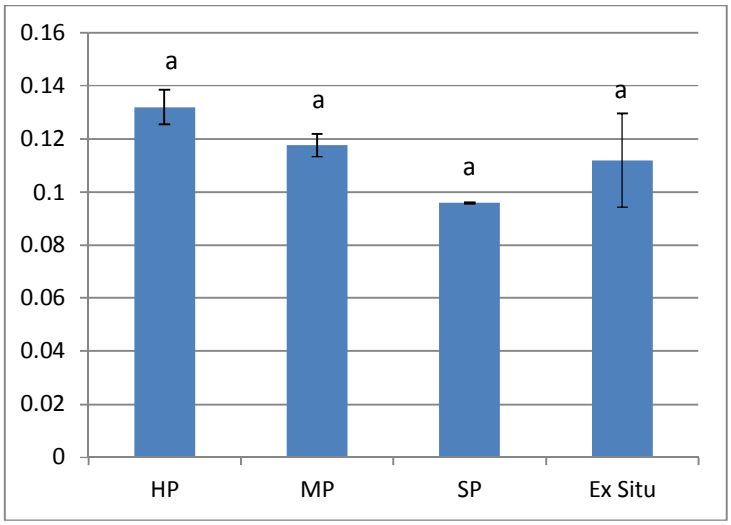


Figure 40: Cr distribution in tobacco fruits (mg.kg^{-1}).

- HP: High pollution; MP: Medium pollution; SP: Slight pollution; Ex-situ: reference plot.
- Values with the same letter for each element are statically not different according to sheffe's test " P<0.05"

Figures 41, 42, 43 and 44 shows the Mn distribution in tobacco plant. The differences between in-situ and ex-situ were significant for all plant parts. The content of manganese in roots, stems, leaves and fruits ranged from 0.02 - 0.06, 7.3 - 24.8, 12.0 - 66.43, 0.03 - 0.07 mg.kg^{-1} respectively.

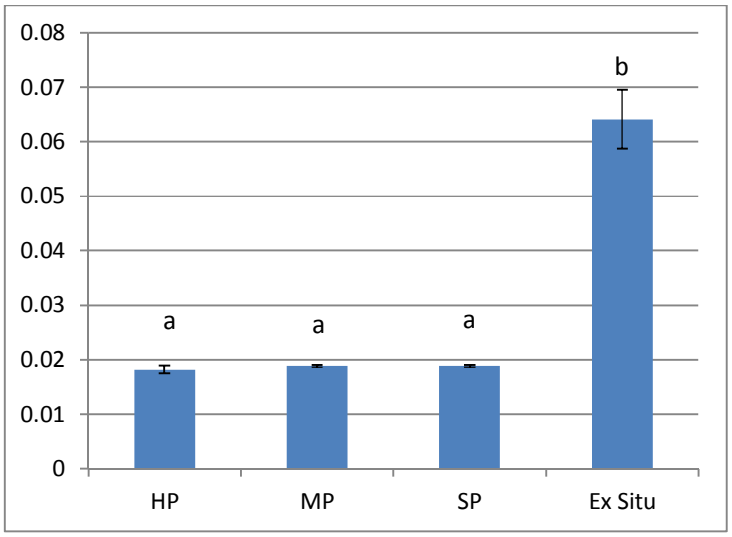


Figure 41: Mn distribution in tobacco roots (mg.kg^{-1})

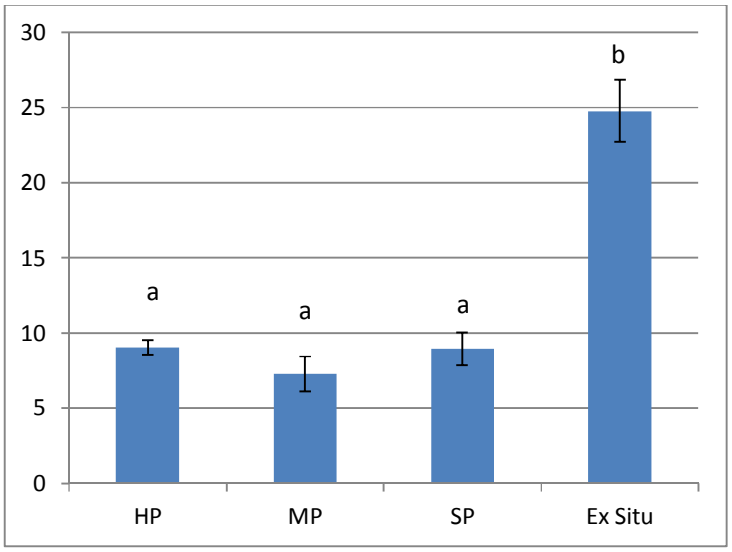


Figure 42: Mn distribution in tobacco stems (mg.kg^{-1})

- HP: High pollution; MP: Medium pollution; SP: Slight pollution; Ex-situ: reference plot.
- Values with the same letter for each element are statically not different according to sheffe's test " P<0.05"

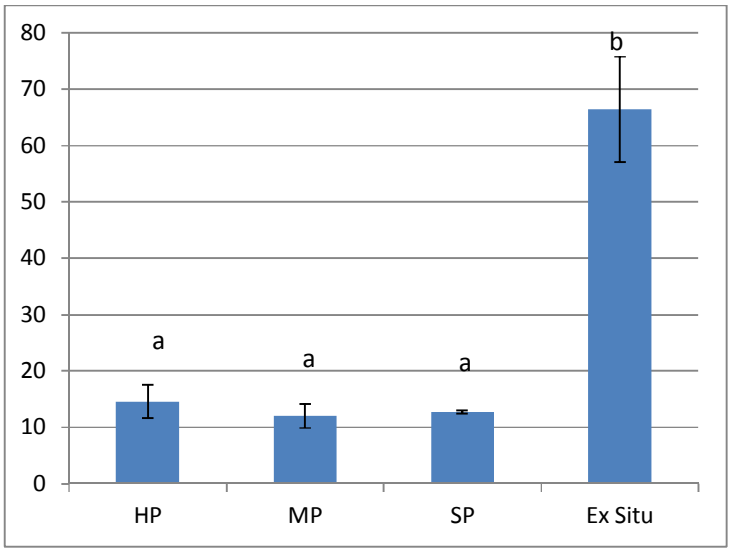


Figure 43: Mn distribution in tobacco leaves (mg.kg^{-1})

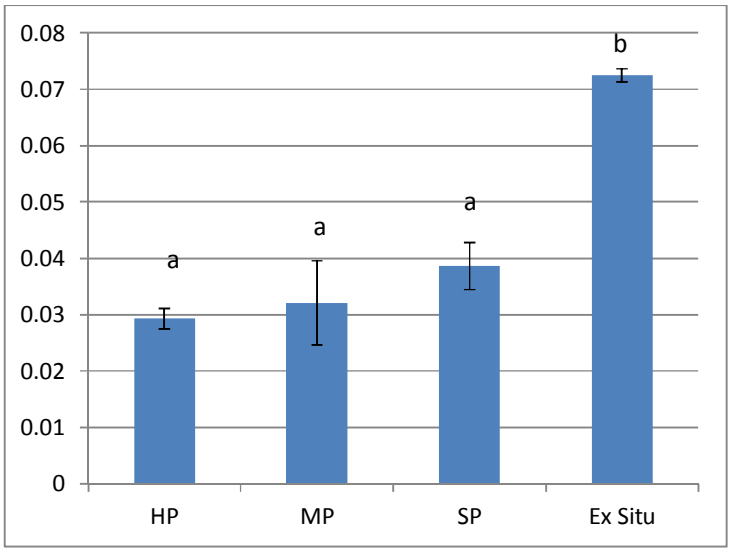


Figure 44: Mn distribution in tobacco fruits (mg.kg^{-1})

- HP: High pollution; MP: Medium pollution; SP: Slight pollution; Ex-situ: reference plot.
- Values with the same letter for each element are statically not different according to sheffe's test " $P<0.05$"

The Zn content in tobacco plant parts; roots, stems, leaves and fruits in polluted soil was 0.16, 40.9, 66.2, and 0.2 $mg.kg^{-1}$ respectively. The zinc content in these plant parts in untreated part was 0.12, 23.0, 55.3, 0.12 $mg.kg^{-1}$ respectively. The differences of zinc content were significant only roots and fruits (figures 45, 46, 47 and 48).

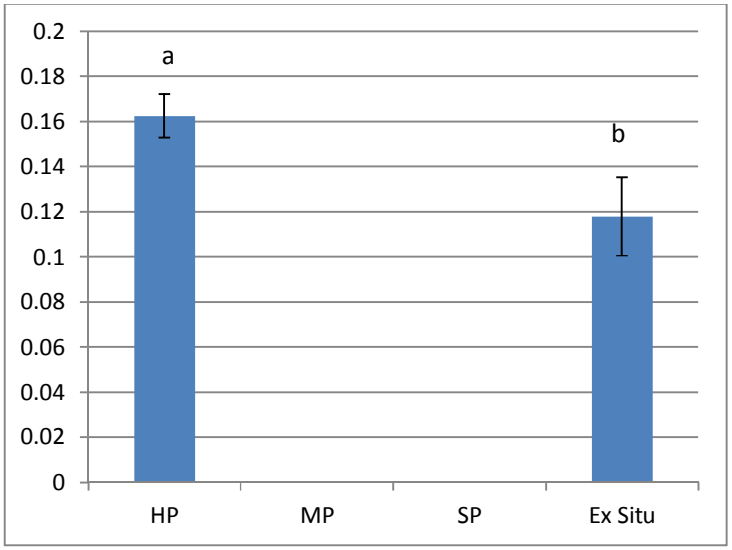


Figure 45: Zn distribution in tobacco roots ($mg.kg^{-1}$)

- HP: High pollution; MP: Medium pollution; SP: Slight pollution; Ex-situ: reference plot.
- Values with the same letter for each element are statically not different according to sheffe's test " $P<0.05$"

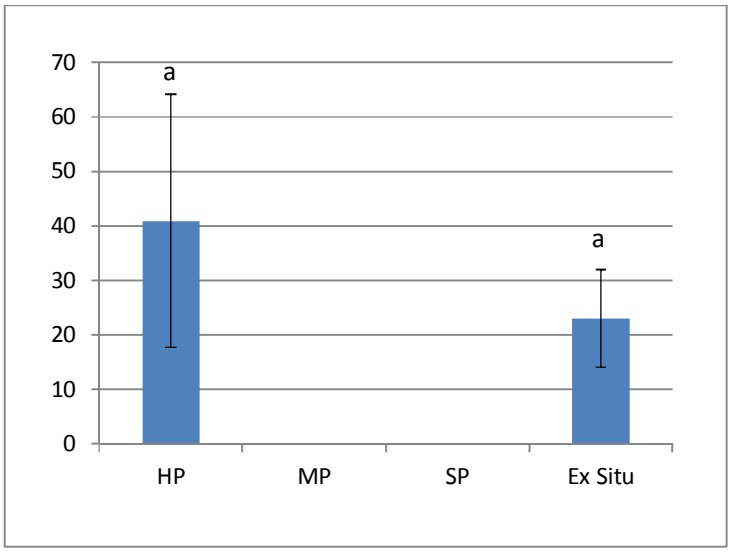


Figure 46: Zn distribution in tobacco stems (mg.kg^{-1})

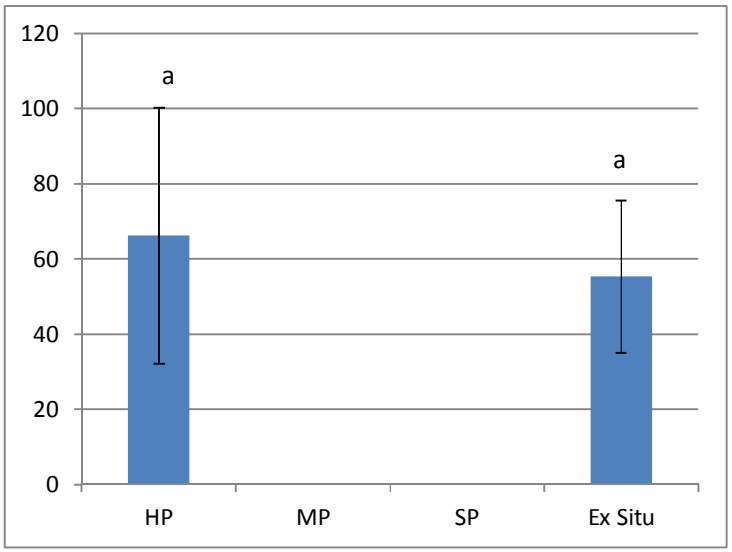


Figure 47: Zn distribution in tobacco leaves (mg.kg^{-1})

- HP: High pollution; MP: Medium pollution; SP: Slight pollution; Ex-situ: reference plot.
- Values with the same letter for each element are statically not different according to sheffe's test " $P<0.05$"

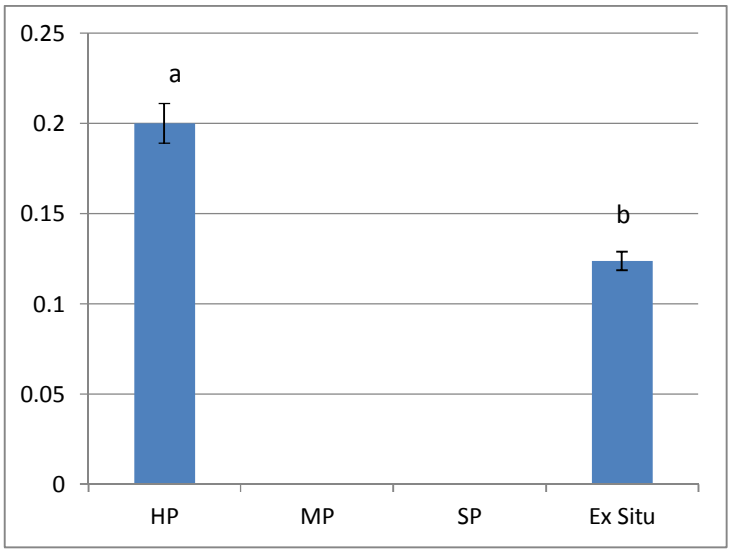
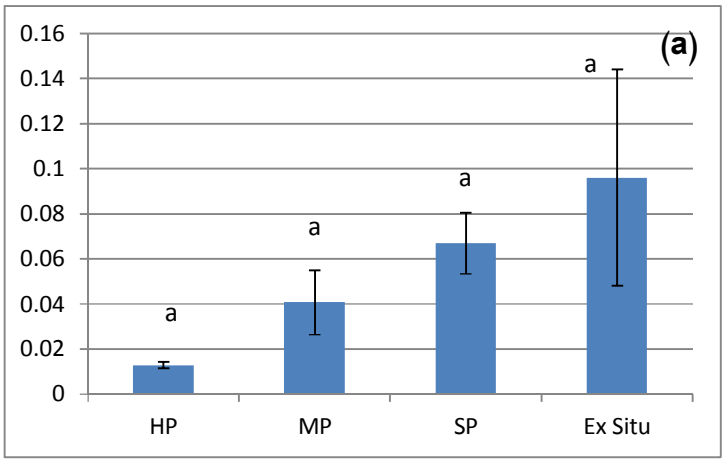


Figure 48: Zn distribution in tobacco fruits (mg.kg^{-1})

- HP: High pollution; MP: Medium pollution; SP: Slight pollution; Ex-situ: reference plot.
- Values with the same letter for each element are statically not different according to sheffe's test " $P<0.05$"

5.9 Bioaccumulation Factor (*f*)

Bioaccumulation factor (*f*) was calculated for corn and tobacco plants in order to evaluate the phytoremdiation efficiency for polluted soil. *f* value of corn for Cr, Mn, and Zn ranged from 0.01 - 0.10, 0.04 - 0.12 and 0.37 - 0.92 respectively (figure 49). While the *f* value of tobacco plant for Cr, Mn, and Zn was 0.01 - 0.06, 0.06 - 0.17, and 0.3 - 0.76 respectively (figure 50). The differences of *f* value between polluted soil and untreated part for Cr and Zn were not significant for both plants and significant for Mn metal.



- HP: High pollution; MP: Medium pollution; SP: Slight pollution; Ex-situ: reference plot.
- Values with the same letter for each element are statically not different according to sheffe's test " P<0.05"

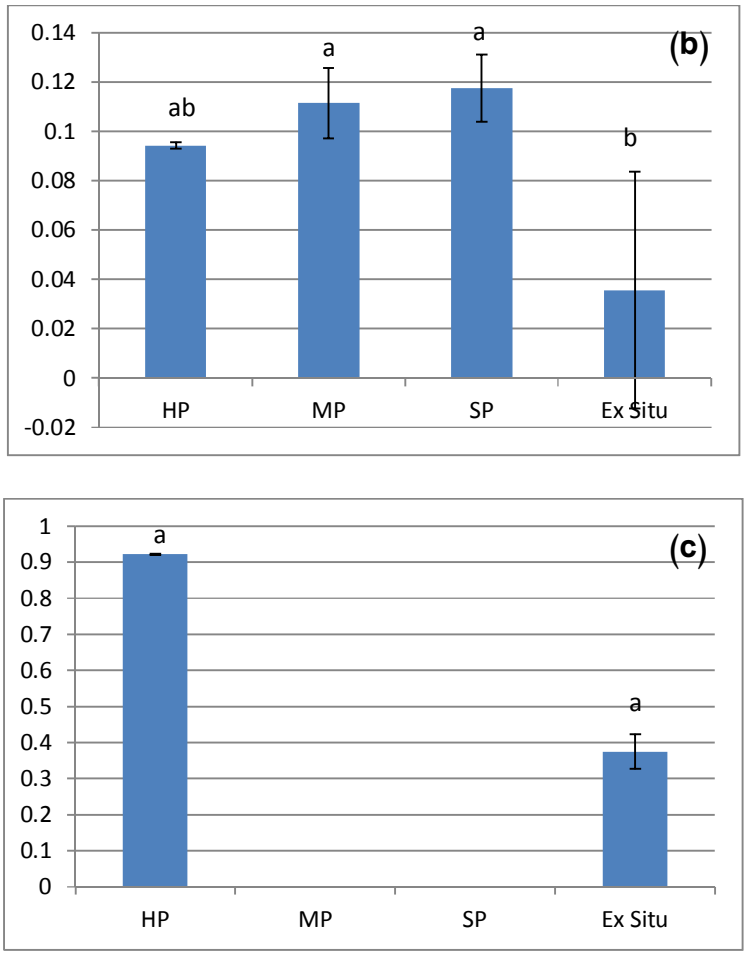


Figure 49: Bioaccumulation factor for corn plant; (a) Cr, (b) Mn and (c) Zn ($mg.kg^{-1}$)

- HP: High pollution; MP: Medium pollution; SP: Slight pollution; Ex-situ: reference plot.
- Values with the same letter for each element are statically not different according to sheffe's test " $P<0.05$"

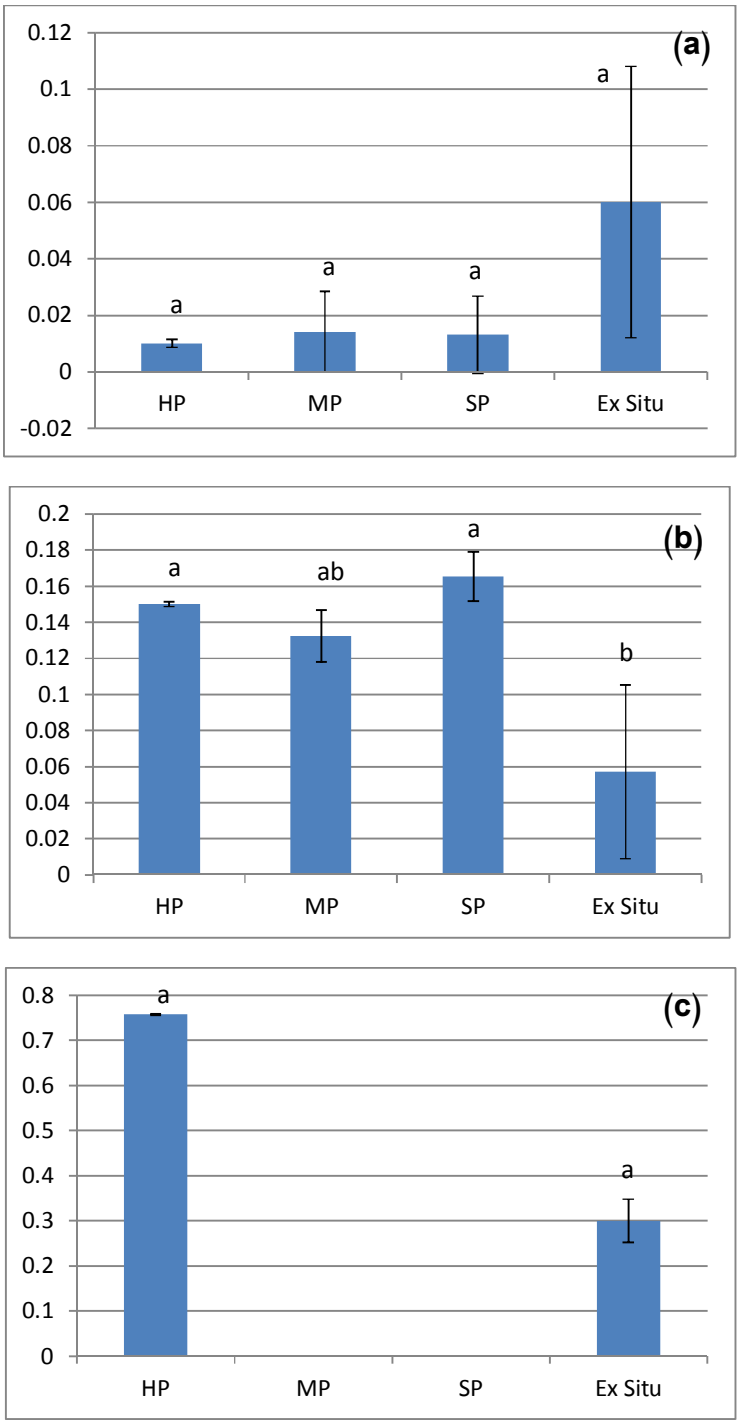


Figure 50: Bioaccumulation factor for tobacco plant; (a) Cr, (b) Mn and (c) Zn.

- HP: High pollution; MP: Medium pollution; SP: Slight pollution; Ex-situ: reference plot.
- Values with the same letter for each element are statically not different according to sheffe's test " $P<0.05$"

6 Discussion

6.1 Soil pH

There are clear variations in the soil pH between various pollution levels. The high soil pH of HP plot indicates that the untreated wastewater that has been discharged over a decade's contains various chemical compounds, in particular Ca-compounds, that has alkaline reaction. This soil pH is not optimal for most plants, although some plants prefer such high soil pH [60]. The high soil alkalinity could be due to proximity of sources of the wastewater to the study site, which already contains wastes that may raise soil pH such as tanneries and calcareous wastes [61, 62, 63 and 64]. On other hand, the soil in study area is considered as calcareous soil, and CaCO3 content is around 62% [65].

6.2 Soil Electrical Conductivity (EC)

The EC of soil in assessed plots ranged from 0.3- 0.4. These EC values are considered suitable for plant growth [60]. Soil electrical conductivity is usually influenced by a combination of physio-chemical factors, including soluble salts, clay content, minerals, organic matter, bulk density, water content and soil temperature [66]. The EC variation affects mainly the anions types, whereas cation types are not noticeably affected with relatively low cation exchange capacity. In addition to that, there is a clear correlation between pH and EC

values. Ec increases with pH decrease [67]. Electrical conductivity has a positive correlation with metals [68].

6.3 Plant Height

The growth rates of both corn and tobacco plants in the highly polluted plots were significantly lower than the reference plot (ex situ). This difference could be due to the variation in the pH and accumulation of pollutants in soil, mainly chromate that was used in tannery processing and stone cutting waste. Taking into account that Cr is considered as a cation, it may influence negatively the availability of another cations (e.g. K^+), which are essential for plant growth and development. However, this negative impact of Chromium was noticeable more at post-germination phase. The amount of minerals stored in seeds may be enough essential for germination.

Another factor is the toxic effect of heavy metals. Various studies showed that heavy metals affect negatively the vegetative growth of plants and usually cause growth inhibition [69], in particular at the early stage of growth. It is assumed that the pollution of heavy metals resulted in a reduction of photosynthesis because seedling growth is known to be more sensitive to such a type of abiotic stress [70, 71]. The polluted soil with heavy metals, the plant growth reduces as growth rate increase in particular with high concentration of heavy metals [72]. Similar to our study, increase in chromate levels in soil caused growth inhibition, most probably due to a reduction in photosynthesis efficiency [73]. The high concentration of

chromium can disturb chloroplast, and thereby disturbing the photosynthesis process. Furthermore, chromium is a redox metal with a redox potential that exceeds other metals like Ni, Zn, Fe. This property of chromium is directly linked to the oxidative stress in plants [74]. Additionally, high concentration of chromium may result in lower stomatal conductance [75]. Further, chromium may affect growth of roots, stem, and leaves, which also affect the accumulation of total dry matter, and subsequently the yield. It is worth mentioning here that chromium induces the production of reactive oxygen species (ROS) leading to oxidative stress, which may explain the external injury symptoms observed on plants [76].

6.4 Heavy Metal Content in Soil before Planting

In Palestine, there is no Palestinian standard for the safe levels of heavy metals in soils. Accordingly, it is possible to assess the degree of contamination between experiment plots according to the typical trace element content in soil shown in Table 1 [77].

Table 1: Typical Trace element content in soil in mg.kg-1

Element	Soil
Chromium	10-50
Manganese	300-1000
Zinc	20- 200

The chromium content in the polluted soil of the studied sites was 5 times higher than typical content, manganese content was 13 times lower than the typical content, and zinc content was within normal range. The high chromium level is directly related to the discharge of untreated tanneries wastes that originate from 10 tannery factories in the study area. Chromium salts, in particular chromium chloride, which is widely used for tannery industry, is considered the main constituent of tannery process [78]. In this sense, chromium is the primary threat when tanning comes in practice [79]. Therefore, the untreated tannery waste is considered the main pollutant source in Wadi AlSamin area. In this context, the high content of chromium in soil has various adverse impacts on the soil, mainly on divalent cations [80], since chromium competes with various cations [81]. The strongest interference is between Cr and other divalent cations (Mn, Co, Pb), particularly at high soil pH, where the Cr oxidative capacity increases leading to the oxidation of Mn [82, 83]. Other studies have addressed Cr speciation reaction with different soil component. It is reported that Cr affected these components in the following order: $Fe(OH)_3$> $CaCO_3$> kaolinite > MnO_2> natural organic matter, and the oxidation of Cr(III) to Cr(VI) is in the order $Fe(OH)_3$> NOM > kaolinite> $CaCO_3$> MnO_2 [84]. This may explain the marked lower content of manganese in polluted soil than typical content. The low level of Mn in polluted soil may refer to the leaching Mn by continuous flow of. Zinc content was found relatively within moderate value.

6.5 Heavy Metal Content in Plant

The total content of metals in whole plant with its distribution through plant axis was illustrated in section 5.7. The highest amounts of heavy metals (Cr, Mn, and Zn) were in the leaves. Basically the uptake of heavy metals by plants is a function of external concentration [85] and transpiration. At the same time, the mechanisms of metals accumulation involve extracellular and intracellular metal chelation, precipitation, compartmentalization and translocation in the vascular system [86]. Moreover, the accumulation and distribution of heavy metals in the plant parts are highly dependent on plant species, element species, pH, cation exchange capacity, dissolved oxygen, temperature, and secretion of roots [87]. Concerning chromium accumulation, studies have shown that the chromium metal tends to accumulate in leaves, stem and roots [88], which is the similar to the results obtained in this study. A similar trend was also evident for manganese as the most accumulation occurred in leaves [89]. Taking into account that Mn is considered as an essential element for plant [90], whose accumulation at low levels is not lethal. This trend of accumulation of metals in leaves is clearly connected to the transpiration process, since leaves always show the highest rates of transpiration [91]. The extent of heavy metals accumulation in plant parts can be compared with the typical trace element content of vegetative parts [77], as shown in table 2.

Table 2: Typical trace element content in vegetative aboveground palnt parts ($mg.kg^{-1}$)

Element	plant
Chromium	0.1-0.5
Manganese	20-400
Zinc	20-100

This comparison clearly indicates that the chromium content in vegetative parts of plants in the treated plot (16.3 $mg.kg^{-1}$) was much higher than the typical range. These results also indicate that plants can be used to remediate soils polluted with chromium.

6.6 Assessing the Efficiency of Phytoextraction with Plant

The assessment of plant efficiency for the metals uptake depends on the target value sought for polluted soil that can be achieved by repeated cropping until the target metal concentration drops to the acceptable limit. The metal uptake and biomass production are considered an important indicator for the reduction of metal concentration [92]. The soil-plant transfer factor or bioaccumulation factor (f) is expressed as the ratio of plant metal concentration divided by the total metal concentration in soil as indicated in equation 1. As higher f factor indicates higher efficiency in phytoextraction [93, 95].

$$\text{Bioaccumulation factor "ƒ"} = \frac{metal\ concentration\ in\ maize\ shoots}{metal\ concetration\ in\ soil} \ldots (1)$$

The calculated bioaccumulation factor "f" of metals in plant shoots is given in figure 49 and 50. The mean$f$ value for corn plants with Cr as a pollutant metal was 0.05 mg.kg^{-1} while in tobacco plant was reported 0.02 mg kg^{-1}. Regarding to the other metals, f for Mn in tobacco 0.13 was higher than in corn 0.09 where bioaccumulation factor f for Zn in both plant was 0.3. These f values are important since both corn and tobacco plants survived under high pollution conditions. Therefore, on the long-term these plants can be used to remediate polluted soils. Recent studies have considered corn a potential candidate for phytoremediation [94], with a measured bioaccumulation factor in contaminated soil of 0.33 [95]. Furthermore, others have evaluated the chromium content in corn shoot with concentrations of 50 and 16.6 mg/kg based contamination of soil with soil improve additives [96, 97] where in this study the concentration was 6 mg/kgin corn plant and 2 mg/kg in tobacco without any additives under natural condition. In addition to that, the studies have targeted ornamental plant for remediation of chromium with f range of 0.1 - 0.88 [98].

7 Conclusion

The continuous application of untreated wastewater for the last 30 years has resulted in high accumulation of heavy metals in soil. The application of phytoremediation in polluted soil with heavy metals has a positive impact. It was concluded that the corn plant was more efficient than tobacco for chromium remediation while tobacco was more efficient for manganese metal. In addition, it was found that among the investigated heavy metals, chromium, manganese and zinc, the chromium metal was the most pollutant element and mostly concentrated in the leaves. This finding allows recommending farmers to get rid of those consumable plants that are cultivated in the investigated area.

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Annexes

Annex 1. pH Variation

- **pH variation of soil before planting**

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.548	3	.183	5.020	.030
Within Groups	.291	8	.036		
Total	.839	11			

- **Homogeneous Subsets**

Scheffe[a]

level	N	Subset for alpha = .05	
	1	2	1
Ex-situ	3	7.2333	
SP	3	7.3000	7.3000
MP	3	7.5167	7.5167
HP	3		7.7800
Sig.		.402	.085

Means for groups in homogeneous subsets are displayed.
a: Uses Harmonic Mean Sample Size = 3.000.

- **pH variation of soil after planting with corn plant :**

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.248	3	.083	1.558	.273
Within Groups	.424	8	.053		
Total	.672	11			

- **Homogeneous Subsets**

Scheffe[a]

level	N	Subset for alpha = .05
	1	1
Ex-situ	3	7.2400
MP	3	7.3633
HP	3	7.4600
SP	3	7.6333
Sig.		.297

Means for groups in homogeneous subsets are displayed.
a: Uses Harmonic Mean Sample Size = 3.000.

- **pH variation of soil after planting with tobacco plant**

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.423	3	.141	2.812	.108
Within Groups	.402	8	.050		
Total	.825	11			

Scheffe[a]

level	N	Subset for alpha = .05
	1	1
Ex-situ	3	7.3000
MP	3	7.6967
SP	3	7.7267
HP	3	7.7667
Sig.		.170

Means for groups in homogeneous subsets are displayed.
a: Uses Harmonic Mean Sample Size = 3.000.

Annex 2. EC Variation

- **EC variation of soil before planting**

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.013	3	.004	1.067	.416
Within Groups	.033	8	.004		
Total	.047	11			

Scheffe [a]

level	N	Subset for alpha = .05
	1	1
MP	3	.3000
SP	3	.3000
HP	3	.3667
Ex-situ	3	.3667
Sig.		.672

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

- **EC variation of soil after planting with corn plant**

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.003	3	.001	.667	.596
Within Groups	.013	8	.002		
Total	.017	11			

Scheffe[a]

Level	N	Subset for alpha = .05
	1	1
HP	3	.2000
MP	3	.2000
SP	3	.2333
Ex-situ	3	.2333
Sig.		.802

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

- **EC variation of soil after planting with tobacco plant :**

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.009	3	.003	.407	.752
Within Groups	.060	8	.008		
Total	.069	11			

Scheffe[a]

Level	N	Subset for alpha = .05
	1	1
MP	3	.1667
SP	3	.2000
Ex-situ	3	.2333
HP	3	.2333
Sig.		.827

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

Annex 3. Plant Height

- **Height variation of corn plant**

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.198	3	.399	22.326	.000
Within Groups	.143	8	.018		
Total	1.341	11			

Scheffe[a]

Level	N	Subset for alpha = .05	
	1	2	1
MP	3	1.2833	
SP	3	1.3733	
HP	3	1.3800	
Ex-situ	3		2.0700
Sig.		.852	1.000

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

- **Height variation of tobacco plant**

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.054	3	.018	6.820	.014
Within Groups	.021	8	.003		
Total	.074	11			

Scheffe[a]

Level	N	Subset for alpha = .05	
	1	2	1
SP	3	.3300	
MP	3	.3400	
HP	3	.3667	.3667
Ex-situ	3		.4967
Sig.		.854	.082

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

Annex 4. Biomass

- **Biomass of corn plant**

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.005	3	.002	16.077	.001
Within Groups	.001	8	.000		
Total	.006	11			

Scheffe[a]

Level	N	Subset for alpha = .05	
	1	2	1
HP	3	.0500	
SP	3	.0500	
MP	3	.0567	
Ex-situ	3		.1000
Sig.		.890	1.000

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

- **Biomass of tobacco plant**

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.001	3	.000	12.667	.002
Within Groups	.000	8	.000		
Total	.001	11			

Scheffe[a]

Level	N	Subset for alpha = .05	
	1	2	1
HP	3	.0100	
MP	3	.0167	
SP	3	.0167	
Ex-situ	3		.0300
Sig.		.330	1.000

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

Annex 5. Leaf Area Index "LAI"

- **LAI of corn plan**

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.935	3	.645	1.187	.374
Within Groups	4.346	8	.543		
Total	6.281	11			

Scheffe[a]

Level	N	Subset for alpha = .05
	1	1
HP	3	7.5300
SP	3	7.6000
MP	3	7.8800
Ex-situ	3	8.5467
Sig.		.461

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

- **LAI of tobacco plant**

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.900	3	.633	3.053	.092
Within Groups	1.659	8	.207		
Total	3.559	11			

Scheffe[a]

Level	N	Subset for alpha = .05
	1	1
MP	3	1.0367
SP	3	1.1633
HP	3	1.4767
Ex-situ	3	2.0667
Sig.		.128

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

Annex 6. Heavy Metal

- **Heavy metal content in soil before planting**
- **Chromium.**

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	8869.667	3	2956.556	1.857	.215
Within Groups	12738.000	8	1592.250		
Total	21607.667	11			

Scheffe[a]

Level	N	Subset for alpha = .05
	1	1
Ex-situ	3	101.3333
SP	3	121.3333
MP	3	147.0000
HP	3	173.6667
Sig.		.255

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

- **Manganese**

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	524780.333	3	174926.778	1974.714	.000
Within Groups	708.667	8	88.583		
Total	525489.000	11			

Scheffe[a]

Level	N	Subset for alpha = .05	
	1	2	1
SP	3	44.3333	
MP	3	48.6667	
HP	3	53.3333	
Ex-situ	3		531.6667
Sig.		.720	1.000

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

- **Zinc**

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	15470.229	3	5156.743	6.827	.013
Within Groups	6042.833	8	755.354		
Total	21513.063	11			

Scheffe[a]

Level	N	Subset for alpha = .05	
	1	2	1
MP	3	.0000	
SP	3	.0000	
HP	3	45.3333	45.3333
Ex-situ	3		86.1667
Sig.		.323	.402

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

- **Heavy metals in soil after planting.**
- **Chromium content in soil after planting with corn plant.**

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	12088.667	3	4029.556	12.833	.002
Within Groups	2512.000	8	314.000		
Total	14600.667	11			

Scheffe[a]

Level	N	Subset for alpha = .05	
	1	2	1
Ex-situ	3	79.0000	
SP	3	123.6667	123.6667
MP	3	127.3333	127.3333
HP	3		168.6667
Sig.		.061	.082

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

- **Chromium content in soil after planting with tobacco plant.**

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	7972.333	3	2657.444	10.763	.004
Within Groups	1975.333	8	246.917		
Total	9947.667	11			

Scheffe[a]

Level	N	Subset for alpha = .05	
	1	2	1
Ex-situ	3	82.0000	
SP	3	118.6667	118.6667
MP	3		129.0000
HP	3		153.6667
Sig.		.114	.135

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

- **Heavy metal content in corn plant " Vegetative above ground growth parts"**

- **Chromium.**

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	53.554	3	17.851	1.441	.301
Within Groups	99.102	8	12.388		
Total	152.656	11			

Scheffe[a]

Level	N	Subset for alpha = .05
	1	1
HP	3	2.2167
Ex-situ	3	6.0300
MP	3	6.0833
SP	3	8.0467
Sig.		.319

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

- **Manganese.**

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	419.972	3	139.991	8.738	.007
Within Groups	128.163	8	16.020		
Total	548.135	11			

Scheffe[a]

Level	N	Subset for alpha = .05	
	1	2	1
HP	3	5.0233	
SP	3	5.2233	
MP	3	5.3133	
Ex-situ	3		18.8467
Sig.		1.000	1.000

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

- **Zinc.**

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	3078.363	3	1026.121	1.328	.332
Within Groups	6182.365	8	772.796		
Total	9260.728	11			

Scheffe[a]

Level	N	Subset for alpha = .05
	1	1
MP	3	.0000
SP	3	.0000
Ex-situ	3	27.1867
HP	3	35.7300
Sig.		.516

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

- **Heavy metal content in corn of all plant parts**
- **Chromium.**
- **Roots**

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.001	3	.000	1.926	.204
Within Groups	.001	8	.000		
Total	.002	11			

Scheffe[a]

Level	N	Subset for alpha = .05
	1	1
MP	3	.1300
HP	3	.1433
SP	3	.1467
Ex-situ	3	.1533
Sig.		.222

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

- **Stem**

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	39.353	3	13.118	.715	.570
Within Groups	146.853	8	18.357		
Total	186.207	11			

Scheffe[a]

Level	N	Subset for alpha = .05
	1	1
HP	3	3.1333
MP	3	5.1000
Ex-situ	3	7.0333
SP	3	7.8000
Sig.		.637

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

- **Leaves**

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	263.727	3	87.909	.952	.460
Within Groups	738.800	8	92.350		
Total	1002.527	11			

Scheffe[a]

Level	N	Subset for alpha = .05
	1	1
HP	3	3.4667
Ex-situ	3	11.0333
MP	3	13.0333
SP	3	16.2000
Sig.		.492

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

- **Fruits**

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.028	3	.009	42.173	.000
Within Groups	.002	8	.000		
Total	.030	11			

Scheffe[a]

Level	N	Subset for alpha = .05		
	1	2	3	1
Ex-situ	3	.0167		
HP	3		.0600	
MP	3			.1133
SP	3			.1433
Sig.		1.000	1.000	.193

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

- **Manganese**

- **Roots**

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.004	3	.001	42.250	.000
Within Groups	.000	8	.000		
Total	.004	11			

Scheffe[a]

Level	N	Subset for alpha = .05	
	1	2	1
HP	3	.0100	
MP	3	.0100	
SP	3	.0100	
Ex-situ	3		.0533
Sig.		1.000	1.000

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

- **Stem**

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	233.069	3	77.690	2.726	.114
Within Groups	228.000	8	28.500		
Total	461.069	11			

Scheffe[a]

Level	N	Subset for alpha = .05
	1	1
MP	3	2.7667
SP	3	3.4333
HP	3	5.4333
Ex-situ	3	13.8000
Sig.		.174

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

- **Leaves**

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2190.122	3	730.041	2.629	.122
Within Groups	2221.527	8	277.691		
Total	4411.649	11			

Scheffe[a]

Level	N	Subset for alpha = .05
	1	1
HP	3	9.6333
SP	3	12.2333
MP	3	13.1667
Ex-situ	3	42.7333
Sig.		.197

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

- **Fruits**

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.000	3	.000	1.000	.441
Within Groups	.000	8	.000		
Total	.000	11			

Scheffe[a]

Level	N	Subset for alpha = .05
	1	1
HP	3	.0100
MP	3	.0100
Ex-situ	3	.0100
SP	3	.0133
Sig.		.596

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

- **Zinc**
- **Roots**

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.066	3	.022	15.235	.001
Within Groups	.012	8	.001		
Total	.077	11			

Scheffe[a]

Level	N	Subset for alpha = .05	
	1	2	1
MP	3	.0000	
SP	3	.0000	
Ex-situ	3		.1233
HP	3		.1667
Sig.		1.000	.604

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

- **Stem**

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	14108.697	3	4702.899	.794	.531
Within Groups	47402.133	8	5925.267		
Total	61510.830	11			

Scheffe[a]

Level	N	Subset for alpha = .05
	1	1
MP	3	.0000
SP	3	.0000
Ex-situ	3	59.9667
HP	3	75.4333
Sig.		.705

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

- **Leaves**

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2273.036	3	757.679	2.465	.137
Within Groups	2459.213	8	307.402		
Total	4732.249	11			

Scheffe[a]

Level	N	Subset for alpha = .05
	1	1
MP	3	.0000
SP	3	.0000
Ex-situ	3	21.5333
HP	3	31.6333
Sig.		.258

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

- **Fruits**

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.032	3	.011	39.417	.000
Within Groups	.002	8	.000		
Total	.034	11			

Scheffe[a]

Level	N	Subset for alpha = .05		
	1	2	3	1
MP	3	.0000		
SP	3	.0000		
Ex-situ	3		.0633	
HP	3			.1233
Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

- **Heavy metal content in tobacco plant "Vegetative above ground growth parts"**
- **Chromium**

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	14.262	3	4.754	.596	.635
Within Groups	63.762	8	7.970		
Total	78.023	11			

Scheffe[a]

Level	N	Subset for alpha = .05
	1	1
SP	3	1.6133
HP	3	1.7433
MP	3	2.0033
Ex-situ	3	4.2833
Sig.		.726

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

- **Manganese**

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1218.634	3	406.211	35.692	.000
Within Groups	91.048	8	11.381		
Total	1309.682	11			

Scheffe[a]

Level	N	Subset for alpha = .05	
	1	2	1
MP	3	6.4333	
SP	3	7.2433	
HP	3	7.8867	
Ex-situ	3		30.4300
Sig.		.962	1.000

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

- **Zinc**

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	3013.741	3	1004.580	3.362	.076
Within Groups	2390.238	8	298.780		
Total	5403.980	11			

Scheffe[a]

Level	N	Subset for alpha = .05
	1	1
MP	3	.0000
SP	3	.0000
Ex-situ	3	26.1400
HP	3	35.7700
Sig.		.173

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

- **Heavy metal content in tobacco plant parts**

- **Chromium**
- **Roots**

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.006	3	.002	6.775	.014
Within Groups	.002	8	.000		
Total	.008	11			

Scheffe[a]

Level	N	Subset for alpha = .05	
	1	2	1
Ex-situ	3	.0367	
SP	3	.0733	.0733
MP	3		.0867
HP	3		.0933
Sig.		.146	.575

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

- **Stem**

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	13.897	3	4.632	.645	.607
Within Groups	57.433	8	7.179		
Total	71.330	11			

Scheffe[a]

Level	N	Subset for alpha = .05
	1	1
HP	3	1.6000
SP	3	1.7333
MP	3	2.5667
Ex-situ	3	4.3000
Sig.		.688

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

- **Leaves**

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	60.193	3	20.064	.557	.658
Within Groups	288.053	8	36.007		
Total	348.247	11			

Scheffe[a]

Level	N	Subset for alpha = .05
	1	1
SP	3	3.0000
MP	3	3.3333
HP	3	3.5000
Ex-situ	3	8.4333
Sig.		.750

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

- **Fruits**

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.001	3	.000	1.885	.211
Within Groups	.002	8	.000		
Total	.003	11			

Scheffe[a]

Level	N	Subset for alpha = .05
	1	1
SP	3	.1000
Ex-situ	3	.1133
MP	3	.1167
HP	3	.1300
Sig.		.214

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

- **Manganese**

Annex 3.5.2.1 Roots

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.004	3	.001	48.000	.000
Within Groups	.000	8	.000		
Total	.004	11			

Scheffe[a]

Level	N	Subset for alpha = .05	
	1	2	1
HP	3	.0200	
MP	3	.0200	
SP	3	.0200	
Ex-situ	3		.0600
Sig.		1.000	1.000

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

- **Stem**

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	608.309	3	202.770	38.429	.000
Within Groups	42.212	8	5.276		
Total	650.521	11			

Scheffe[a]

Level	N	Subset for alpha = .05	
	1	2	1
MP	3	7.2667	
SP	3	8.9667	
HP	3	9.0333	
Ex-situ	3		24.7833
Sig.		.828	1.000

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

- **Leaves**

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	6408.116	3	2136.039	28.059	.000
Within Groups	609.013	8	76.127		
Total	7017.129	11			

Scheffe[a]

Level	N	Subset for alpha = .05	
	1	2	1
MP	3	12.0000	
SP	3	12.7333	
HP	3	14.6000	
Ex-situ	3		66.4333
Sig.		.987	1.000

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

- **Fruits**

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.003	3	.001	15.458	.001
Within Groups	.001	8	.000		
Total	.004	11			

Scheffe[a]

Level	N	Subset for alpha = .05	
	1	2	1
HP	3	.0300	
MP	3	.0333	
SP	3	.0367	
Ex-situ	3		.0700
Sig.		.802	1.000

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

- **Zinc**
- **Roots**

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.062	3	.021	77.583	.000
Within Groups	.002	8	.000		
Total	.064	11			

Scheffe[a]

Level	N	Subset for alpha = .05		
	1	2	3	1
MP	3	.0000		
SP	3	.0000		
Ex-situ	3		.1167	
HP	3			.1633
Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

- **Stem**

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	3549.416	3	1183.139	2.542	.130
Within Groups	3723.093	8	465.387		
Total	7272.509	11			

Scheffe[a]

Level	N	Subset for alpha = .05
	1	1
MP	3	.0000
SP	3	.0000
Ex-situ	3	23.0333
HP	3	40.9333
Sig.		.225

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

- **Leaves**

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	11237.756	3	3745.919	3.183	.085
Within Groups	9416.013	8	1177.002		
Total	20653.769	11			

Scheffe[a]

Level	N	Subset for alpha = .05
	1	1
MP	3	.0000
SP	3	.0000
Ex-situ	3	55.2667
HP	3	66.1667
Sig.		.215

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

- **Fruits**

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.087	3	.029	218.062	.000
Within Groups	.001	8	.000		
Total	.088	11			

Scheffe[a]

Level	N	Subset for alpha = .05		
	1	2	3	1
MP	3	.0000		
SP	3	.0000		
Ex-situ	3		.1233	
HP	3			.2000
Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

Annex 7: Bioaccumulation Factor of corn plant

- **Chromium**

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.011	3	.004	1.715	.241
Within Groups	.017	8	.002		
Total	.029	11			

Scheffe[a]

Level	N	Subset for alpha = .05
	1	1
HP	3	.01333
MP	3	.04333
SP	3	.06667
Ex-situ	3	.09667
Sig.		.266

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

- **Manganese**

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.013	3	.004	9.047	.006
Within Groups	.004	8	.000		
Total	.017	11			

Scheffe[a]

Level	N	Subset for alpha = .05	
	1	2	1
Ex-situ	3	.03667	
HP	3	.09333	.09333
MP	3		.11333
SP	3		.12000
Sig.		.075	.553

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

- **Zinc**

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.715	3	.572	.985	.447
Within Groups	4.643	8	.580		
Total	6.357	11			

Scheffe[a]

Level	N	Subset for alpha = .05
	1	1
MP	3	.00000
SP	3	.00000
Ex-situ	3	.37333
HP	3	.92333
Sig.		.560

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

- **Bioaccumulation Factor of tobacco plant**

- **Chromium**

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.006	3	.002	1.069	.415
Within Groups	.014	8	.002		
Total	.020	11			

Scheffe[a]

Level	N	Subset for alpha = .05
	1	1
HP	3	.01000
SP	3	.01333
MP	3	.01667
Ex-situ	3	.06333
Sig.		.527

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

- **Manganese**

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.020	3	.007	9.000	.006
Within Groups	.006	8	.001		
Total	.026	11			

Scheffe[a]

Level	N	Subset for alpha = .05	
	1	2	1
Ex-situ	3	.06000	
MP	3	.13000	.13000
HP	3		.15000
SP	3		.16667
Sig.		.077	.475

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

- **Zinc**

ANOVA

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.150	3	.383	1.621	.260
Within Groups	1.892	8	.236		
Total	3.042	11			

Scheffe[a]

Level	N	Subset for alpha = .05
	1	1
MP	3	.00000
SP	3	.00000
Ex-situ	3	.30000
HP	3	.75667
Sig.		.367

Means for groups in homogeneous subsets are displayed.
a Uses Harmonic Mean Sample Size = 3.000.

معالجة التربة الملوثة بالعناصر السامة في منطقة واد السمن- الخليل- فلسطين باستخدام النباتات

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جامعة بيرزيت

ملخص

منهج استخدام النبات في تنظيف التربة الملوثة "**التكنولوجيا الخضراء**" تم تطبيقه في منطقة واد السمن لمدينة الخليل– فلسطين وذلك من اجل تقييم مدى فعالية النبات في معالجة التربة الملوثة بالعناصر السامة الثقيلة.

تم تنفيذ التجربة تحت الظروف الطبيعية في الحقل لتقييم مدى فعالية نبات الذرة الصفراء والدخان في امتصاص العناصر السامة الثقيلة تحت ظروف النمو الطبيعية بدون اضافة محسنات كيمائية. تم قياس تركيز ثلاثة عناصر سامة ثقيلة (Cr, Mn, Zn) في جميع اجزاء البناتات المستهدفة (الجذر، الساق، الورقة، الثمار) باستخدام جهاز ICP–AES، حيث بينت الدراسة ان تركيز العناصر السامة في جزء اوراق النباتات الاعلى مقارنة بالاجزاء الاخرى لكلا النباتين المستهدفين.

كما بينت الدراسة ان معامل التركيز الحيوي لنبات الذرة الصفراء لعنصر Cr 0.05 اعلى منه لنبات الدخان 0.02 ، بينما كان معامل التركيز الحيوي لعنصر Mn 0.13 لنبات الدخان اعلى منه لنبات الذرة الصفراء 0.09 كما وان معامل التركيز الحيوي لعنصر Zn لكلا النباتين 0.3 .