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Phytoremediation potentials of some selected vegetables on polluted soils in Kano state

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Abstract. Phytoremediation is the process which uses green plants for relief, transfer, stabilization or degradation of pollutants from soil, sediments, surface waters, and groundwater. The phytoremediation potential of five vegetables, Carrot (D.carota), Cabbage (B. oleracea), Tomato (Lycopersicon esculentum), Pepper (C. annum), and Lettuce (L. sativa) planted on contaminated soil samples collected from Challawa Industrial Estate Kano was investigated. The plants were grown in plastic pots and were irrigated using the collected industrial waste water. The growth parameters of the plants were monitored for twelve weeks. Thereafter, the as-grown vegetables were harvested and prepared by means of digestion using aqua regia HNO_3/HCl (1:3) for Atomic Absorption Spectroscopy (AAS) analyses.The mean levels of the metals in the soil from contaminated sites were found to be in sequence of Mg > Fe > Zn> Cu >Mn; control site, Fe>Mg >Mn > Zn > Cu; plant root from contaminated site contained Zn >Mg >Fe >Mn > Cu; whereas plant root from control site had Mg >Fe > Zn >Mn > Cu; Plant shoot from contaminated site showed Zn > Fe >Mn >Mg >Cu; while plant shoot from control site contained Mg >Zn > Fe >Mn > Cu; respectively. The bio-accumulation level of the target metals onthe various parts of the experimented plants confirms their ability for the phytoextraction of different metals from the soil. The results obtained demonstrates the potential of all our experimented plants in phytoremediation of multi-metal in contaminated soils and may serve as uneconomical and innocuous candidates for phytoremediation strategy in the future for controlling metal contamination level in soil.

Key words: Phytoremediation, Phytoextraction, Bioaccumulation factor, Vegetables, Contaminated Soils, AAS.

1 Introduction

Phytoremediation basically refers to the use of plants and associated microorganism to partially or completely remediate selected contaminants from soil, sludge, sediments, waste water and ground water. It can be used for removal of radionuclides, organic pollutant as well as heavy metals [1]. Plants living in metal contaminated sediments can have exceptional properties which make them interesting for phytoremediation [2]. There are proves that many plant species have enormous ability to uptake and accumulate heavy metals and plays an important role in

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sequestering large quantities of metals from the environment by storing them in various tissues[3]. The identification of metal hyper-accumulators, plants capable of accumulating extra-ordinary high metals levels, demonstrates that plants have the genetic potential to clean up contaminated environment. Some tolerating and accumulating plants can absorb heavy metals and then transferring and storing them at the above parts (phytoremediation) [4].

Phytoremediation is a potential remediation technology that can be used to decontaminate environment contaminated with inorganic pollutants. Research related to this relatively new technology needs to be promoted, emphasized, and expanded in developing countries since it is low cost [5]. In situ, solar driven technology makes use of vascular plants to accumulate and translocate metals from root to shoots. Harvesting the plant shoots can permanently remove these contaminants from the environment [6]. Phytoremediation does not have the destructive impact on soil fertility and structure that some more vigorous conventional technologies have such as acid extraction and washing soil. Phytoremediation encompasses five processes of metal removal from soil or water. These processes include rhizofiltration, phytostabilisation, phytoextraction, phytovolatilization and phytodegradation [7].

Phytoremediation potentials of selected plants in industrially contaminated soils using Jatropha (*Jatrophacurcas)*, Neem (*Azadirachtaindica*) and Baobab (*Adansoniadigitata*) was evaluated [8]. The plants were grown under hydroponic greenhouse conditions for thirteen weeks and levels of metals in plants, soil and effluents water were determined using Atomic Absorption Spectrophotometer (AAS). The mean concentrations of the metals ranged from 4.33±0.02mg/kg Pb to 453,15 ±42,32mg/kg Fe and 2.6 ± 0.01 mg/kg to 114.6 ± 23.24 mg/kg for plants grown in the contaminated and control soils respectively. A bioaccumulation factor greater than 1.0 implies the plants can use for phytoextraction. The results suggest that the investigated plants are potentially useful for remediating heavy metals.

Phytoremediation potential of some plants for metals (Cd, Cr, Cu, Fe, Mn, Ni, Pb and Zn) in contaminated soils of Challawa industrial estate, Kano was reported [9]. A total of one hundred and eighty (180) samples comprising of 80 (soils), 20 (effluents), and 80 (plant parts) of Jatropha (*Jatrophacurcas*), Neem (*Azadirachtaindica*) and Baobab (*Adansoniadigitata*) were analyzed. 0.50g of the plant tissue and 1.0g of soil sample and 50mL of the effluents sample were digested using triacid digestion method and the levels of the metals were determined by the use of AAS.

-Criteria for phytoremediation

Plants with both bio-concentration factor and translocation factor greater than one (BCF and TF > 1) have the potential to be used in phytoextraction. Besides, plants with bioconcentration factor greater than one and translocation factor less than one (BCF > 1 and TF<1) have the potential for phytostabilization [9].

-Bioconcentration Factor (BCF)

Bioconcentration factor refers to the plant metal concentration in root and soil metal concentration ratio ([metal] root/[metal]soil). This ratio should be greater than one for a plant to be hyperaccumulator [10].

- Translocation Factor (TF)

Translocation factor generally shows the movement of metal from roots to shoots, indicating the efficiency to uptake the bio-available metals from the system. TF gives the idea whether the plant is an accumulator or not. TF is the ratio of metal concentration in the shoots to the roots ([metals] shoot /[metals]root). It should be greater than one for a plant to be hyperaccumulator [11].

2. Materials and methods

2.1. Study area

Challawa industrial estate is located in Kumbotso Local Government Area of Kano State. It is located in the northern Nigeria covering an area extending between latitude 11° 52' 50° and longitude 8° 28' and 30° (Figure 1) The industries in the Challawa industrial estate range from tanneries, textiles, food and packaging / processing industries.

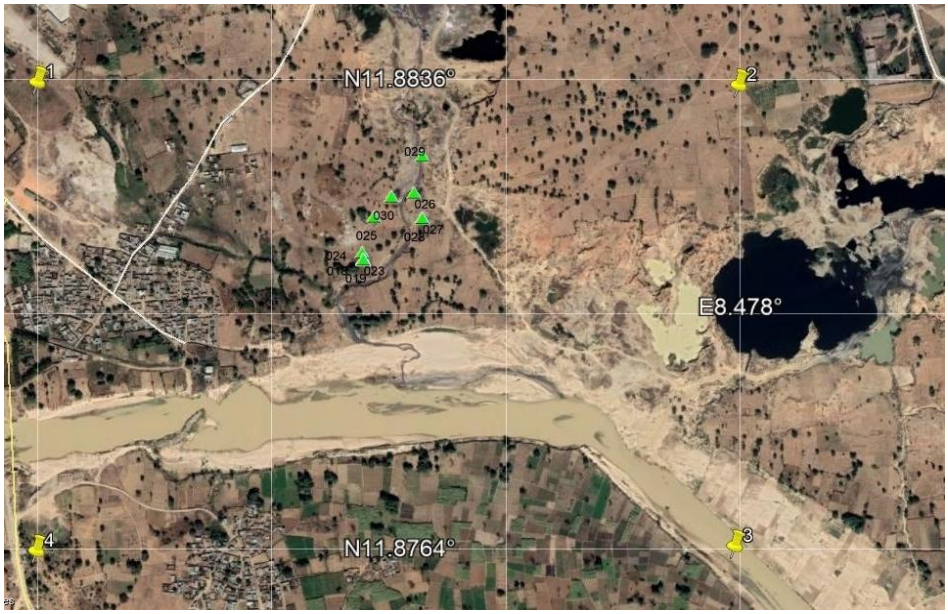

Figure 1: Map of the Sampling Area

2.2. Sampling

Soil samples were collected from the Challawa industrial estate along the effluents discharge channels in black polyethylene bags while the liquid effluents were collected in 25-liter container and transported to the laboratory. Similarly, control soil sample (15.00 kg) were collected from Botanical garden of Bayero University, Kano. The seeds of Carrot (*D.carota*), Cabbage (*B.*

oleracea), Tomato (*Lycopersicoesculentum*), and Pepper (C. *annum*) were obtained from Sharada market in Kumbotso Local Government Area, Kano Kano state Nigeria.

2.3. Sample Preparation

At the end of the experimentation period, the plants were harvested whole from each pot, placed in black plastic bags and taken to the laboratory. The soil sample in each pot was also collected in black plastic bags and taken to the laboratory. The plant samples were washed with ordinary water then with distilled water to remove dirty and dust. The samples were then separated into portions of roots, stems, and leaves and air dried in the laboratory for five weeks. The dried samples were ground into fine powder using ceramic pestle and mortar and stored in stoppered plastic bottles, until used for acid digestion. Soil samples were also air-dried, ground to fine powder using wood pestle and mortar, sieved using a 2mm Nylon Scientific sieve and stored in polythene bags until used for acid digestion.

2.5. Digestion of Plant Sample

The plant tissue sample were weighed (0.5g) and placed in a $30cm^3$ crucible and transferred into a muffle furnace and ashed at 550^oC. The ash was then dissolved in 0.1 M HNO_3, filtered and made up to the mark with 0.1M HNO_3 in $100cm^3$ volumetric flask. The sample were analysed for heavy metals using AAS (Agilent Technologies, 200 series 240FS AA).

2.6. Digestion of Soil Samples

The soil samples were weighed (0.5g) and digested in 12 ml of aqua regia HNO_3/HCl (3:1) on a hot plate for 3 hours at 110^0C until the brown fumes disappeared. Then, 20 mL of distilled water was added and heated until a colorless solution was obtained. The solution was allowed to cool and filtered into a standard volumetric flask (100 mL) using filter paper and the volume was made to the mark with distilled water [12].

2.7. Digestion of effluent Water Samples

The effluents samples were measured (500 cm^3) and filtered using filter paper and acidified with concentrated HNO_3 to bring down the pH to 2.0. $100cm^3$of the acidified effluents were measured and transferred into $250cm^3$ beaker after which $10cm^3$ of concentrated HNO_3/HCl aqua regia was added. The beaker containing the effluents sample was placed on a hot plate and digested in a fumes cupboard until white fumes was observed. The digested sample was transferred to $100cm^3$ volumetric flask and made up to the mark with deionized water [13].

2.8. Data Analysis

Analysis of variance for the growth parameters and heavy metals concentrations in the samples were computed by the Duncan's multiple range test DMRT (p=0.05) method [13]. The statistical variations were considered significant at (p<0.05). Comparison using t-test was also used to detect any significant differences in metal concentrations between plants from polluted and unpolluted (control) sites.

3. Results and Discussion

The results revealed that, the plants can be used for the phytoextraction of the metals from contaminated soils and indicated the trend follows the following sequence; Mg>Fe > Zn > Cu > Mn.

Table1. Concentrations of metals in Plants and Soils from Contaminated and Control Sites.

S/N	Metals	Soil from Contaminated Site (mg/kg)	Soil from Controlled Site (mg/kg)	Plant Root from contaminated Site (mg/kg)	Plant Root from Controlled Site (mg/kg)
1	Fe	266.27 ± 0.02	173.93 ± 0.21	171.73 ± 117	145.53 ± 0.18
2	Mg	618.89 ± 0.18	154.73±0.56	2536.24 ± 3.28	1471.19 ± 1.78
3	Mn	65.00 ± 0.06	64.07 ± 0.06	114.07 ± 0.10	109.00 ± 0.02
4	Zn	90.74 ± 0.10	56.41 ± 0.04	968.92 ± 170.42	142.97 ± 0.04
5	Cu	65.93 ± 0.07	56.41 ± 0.04	66.40 ± 0.04	11.53 ± 0.04

The concentration of metals in the soil, plant roots and shoots were determined and presented as in the Figures 2 − 4. The concentration of copper as shown in Figure 2A, ranged from 23.40 ± 0.02 mg/kg to 65.93 ± 0.07 in the contaminated soil, while in the control site copper concentration ranged from 9.80 ± 0.01 mg/kg to 28.13 ± 0.11 mg/kg.

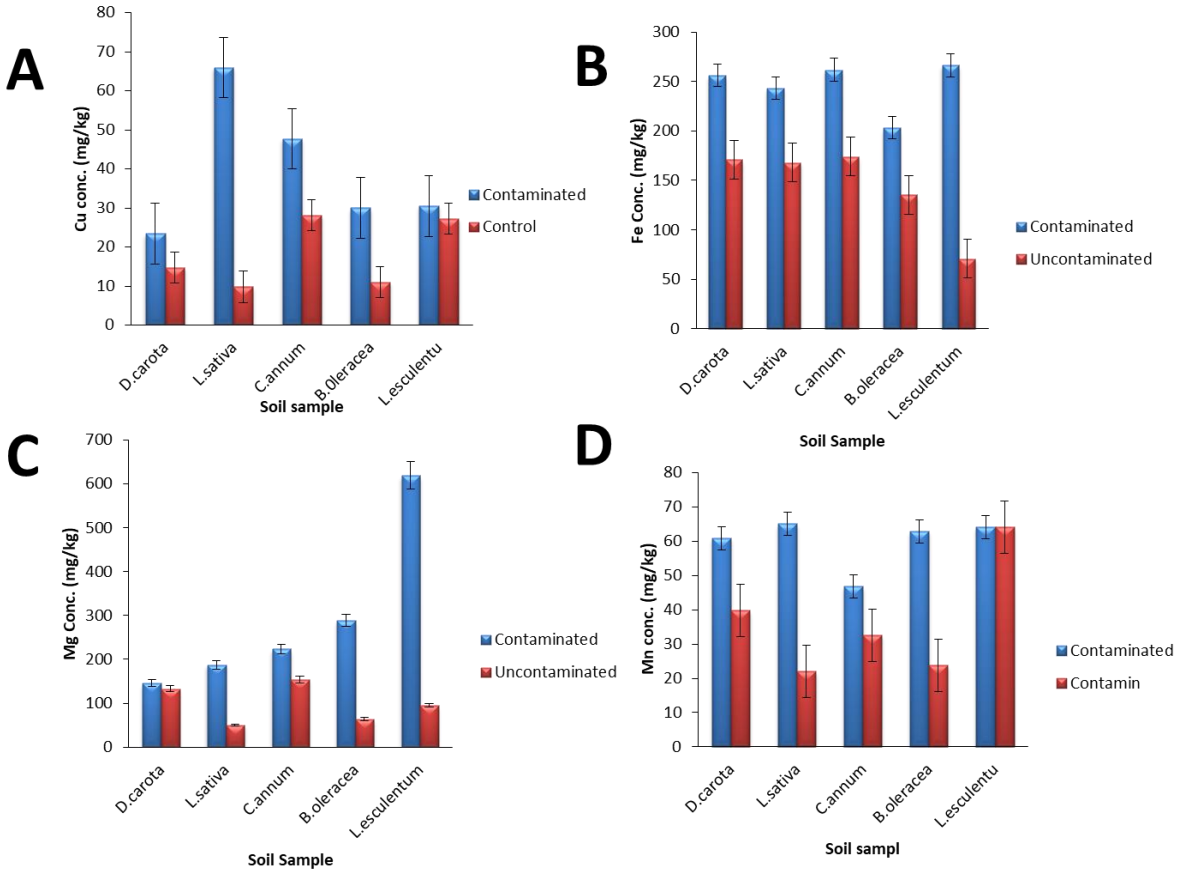

Figure 2. Concentrations of uncontaminated and contaminated soil containing (A) Cu, (B) Fe, (C) Mg, and (D) Mn metals

The concentrations of Cu for soil set by [14] are in the range of 70-80 mg/kg. The average concentration of copper on both sites is below permissible limits as specified by [14]. Figure 2B shows the concentration of iron in the contaminated soil which ranged from 203.20 ± 0.08 mg/kg to 266.27 ± 0.02 mg/kg, whereas concentration found in the control site ranged from 0.77 ± 0.07 mg/kg to 173.93 ± 0.21 mg/kg. Thus, the average iron concentrations for both soils are below permissible limits specified by [15]. Figure 2C shows the concentration of Magnesium in the contaminated soil ranged from 145.93 ± 0.45 mg/kg to 618.89 ± 0.18 mg/kg, while in the control site, it ranged from 28.39 ± 0.09 mg/kg to 154.73 ± 0.56 mg/kg. Figure 2D shows the concentration of Manganese in the contaminated soil ranged from 46.67 ± 0.11 to 65.00 ± 0.06 mg/kg, whereas its concentration in the control site was found in ranged 22.00 ± 06 mg/kg to 64.07 ± 0.06 mg/kg.

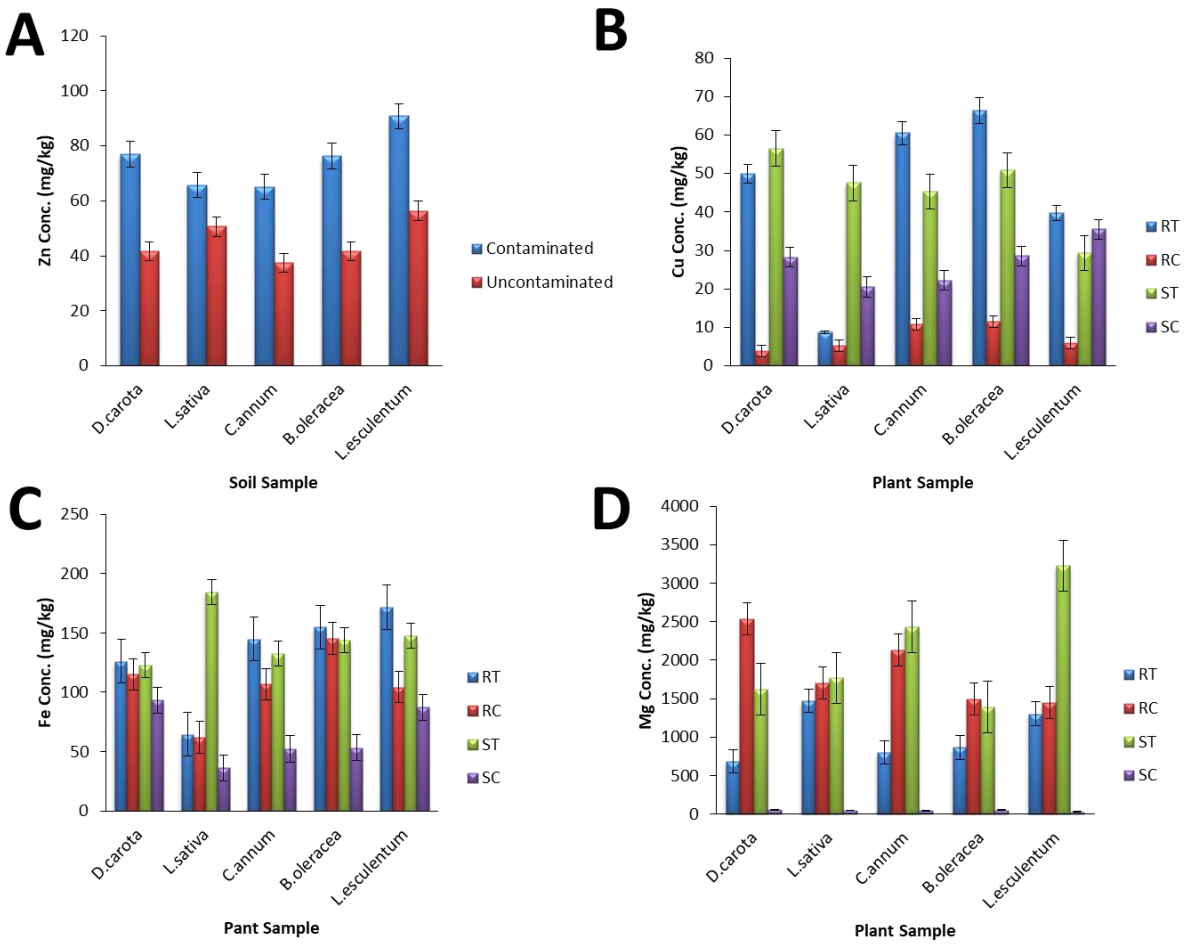

Figure 3. Concentration of Zn (A), in contaminated and uncontaminated soil, and concentrations of Cu (B), Fe (C),and Mg (D) in plant roots and shoots.

From Figure 3A, the concentration of zinc was observed to be in the range 65.80 ± 0.09 mg/kg to 90.74 ± 0.15mg/kg and 37.57 ± 0.10 mg/kg to 56.41 ± 0.04 mg/kg in the contaminated and

control soil respectively. The Concentrations of Zn for soil set by [15] is in the range of 300-400mg/kg. Therefore, the average Zn concentration for both soils is below the permissible limits specified by [15].The concentration of copper in the five different plant root and shoot in contaminated and uncontaminated soil determined is shown in Figure 3B. The concentration of copper ranged from 8.73 ± 0.04 mg/kg to 66.40 ± 0.04 mg/kg in the roots on contaminated site, whereas a concentration range 2.20 ± 0.02 mg/kg to 11.53 ± 0.04 mg/kg was measured the in control site.

On other hand, the concentration of copper in the plant shoot ranged from 29.40 ± 0.03 mg/kg to 56.53 ± 0.03 mg/kg and 20.60 ± 0.04 mg/kg to 20.60 ± 0.04 mg/kg in contaminated and control site respectively. The concentration of copper in plants is 10mg/kg as recommended by WHO [16]. The average concentration of copper is above the permissible limit in contaminated soil. Although Cu is an essential element for human health, excessive intake can impair organs and systems in the human body, possibly causing serious symptoms including nauseas, vomiting, kidney failure and central nervous system depression [16].

The concentration of iron found in the root ranged from 64.67±0.12mg/kg to 171.73±117mg/kg in contaminated site, whereas the concentration of Ironin the control site of the soil ranged from 62.07±0.08mg/kg to 145.53±0.18mg/kg. The concentration of Iron in the shoot (upper part of the plant) ranged from 36.27±0.06mg/kg to 147.33±0.02mg/kg, and 52.20±0.14mg/kg to 184.60 ± 0.11 mg/kg in the contaminated and control site respectively as shown Figure3C. The WHO recommended level of iron in plants is 20 mg/kg [17]. The average concentration of iron in both plants is above the permissible limit. The concentration of Magnesium was observed to be in the range 864.13±0.56mg/kg to 2536.24±3.28mg/kg in the plant root from the contaminated soil, while in the range 687.51±1.66mg/kg to 1471.19±1.78mg/kg for the control site. The concentration of Magnesium in the shoots from the contaminated site ranged from 1394.37±0.54mg/kg to 3228.11±3.07mg/kg, while its concentration in the root from control site ranged from 29.40±0.72mg/kg to 50.80±0.02 mg/kg as presented in Figure3D.

Figure 4A, shows the concentration range of Manganese in the shoots from 79.93±0.05mg/kg to 105.73±0.14 mg/kg on contaminated site, while its concentration in the shoot ranged from 56.93±0.03mg/kg to 128.53±0.02mg/kg in control site. The concentration of Manganese in roots ranged from 88.27±0.02 mg/kg to 9689.20±1704.24 mg/kg. The concentration of zinc ranged from 88.27±0.02mg/kg to 9689.20±1704.24mg/kg from contaminated site, where asits concentration ranged from 88.07±0.21mg/kg to 155.40±0.05mg/kg in root from control site. The concentration of zinc ranged from 130.61±0.10mg/kg to 228.59±0.49mg/kg in shoot on contaminated site, while its concentration on the control site ranged from 129.82±0.04mg/kg to 185.02±0.17mg/kg as shown in Figure 4B. The concentration of zinc is 50mg/kg as set by WHO [18]. Thus, the average zinc concentration of zinc for both plants was observed to be above the permissible limit set by WHO. Zinc is one of the important trace elements that play a vital role in the physiological and metabolic process of many organisms. Nevertheless, higher concentrations of zinc can be toxic to the organism.

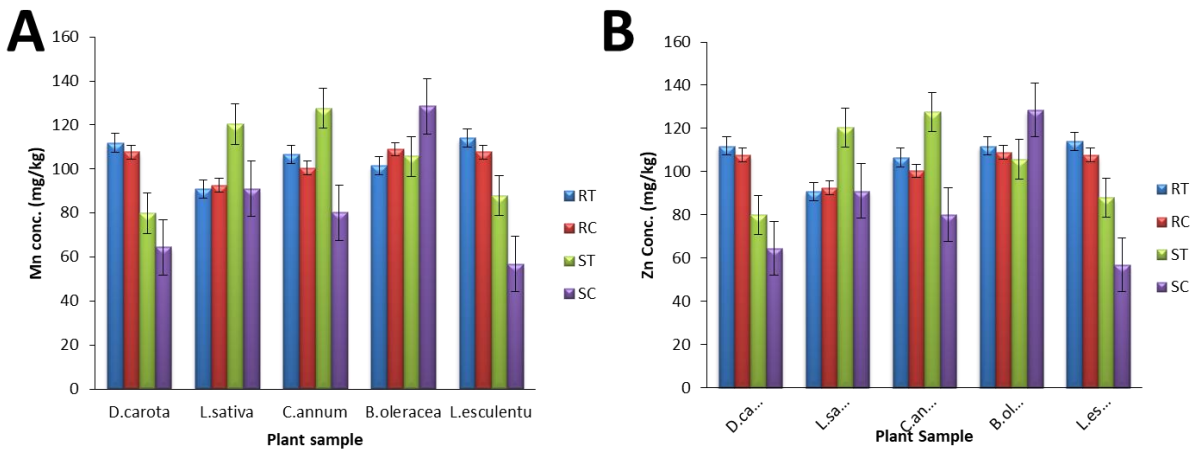

Figure 4. Concentrations of Mn (A), and Zn (B) Metals in Plant Roots and Shoots

4. Conclusion

In this study, the potentials of Carrot (*D.carota*), Tomato (*L. esculentum*) ,Cabbage (*B. oleracea*),Salad (*L.satiaI*),and Pepper (C. *annum*) for the phytoremediation of Cu, Fe, Mg Mn and Zn in contaminated soils were studied and the parameters used in the assessment include plant growth performance, plant biomass, and soil pH. The results revealed that, the vegetables, Carrot (*D.carota*), Tomato (*L. esculentum*),Cabbage (*B. oleracea*), and Salad (*L.satiaI*) were suitable for the uptake, accumulation, and storage of the target metals from contaminated soils. The bioaccumulation and translocation factors were found to be greater than one in all cases, which indicate that the vegetables are good hyper-accumulators and have the potentials for remediation processes. The experimented plants in our study may be considered as promising candidates in the search for phytoremediators in the field technology of phytoremediation.

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