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TOXIC HEAVY METALS ACCUMULATION IN TOMATO PLANT (*Solanum lycopersicum*)

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ABSTRACT

Elemental analysis of the roots, stems, leaves, and fruits of tomato was performed using scanning electron microscopy equipped with energy–dispersive X-ray spectroscopy (SEM-EDS) and Atomic absorption spectroscopy (AAS). irrigation water of tomato plants were found free from heavy toxic metals, (Zn, Cd, Co, Cr, Mn), but have traces of Cu and Pb. Traces of Zn, Cu, Cr, Pb, and Mn were detected in the soil. EDS analysis showed that toxic heavy metals Pb, Co, Cr, Mn, Ti, Zn, and Cu were detected and accumulated in the roots system of tomato, only Pb tranbsfered from the root to stems. Fe found to be accumulated in all parts of tomato plant.

Keywords: tomato plant, SEM-EDS, AAS, toxic heavy metals.

INTRODUCTION

Agricultural soils and irrigation water in many parts of the world are slightly to be contaminated by toxic heavy metals such as zinc (Zn^{2+}), nickel (Ni^{2+}), cadmium (Cd^{2+}), copper(Cu^{2+}), cobalt (Co^{2+}), lead (Pb^{2+}), mercury (Hg^{2+}), arsenic (As^{3+}), and chromium (Cr^{3+}, Cr^{6+}). This could be due to industrial wastewater, sewage sludge applications, phosphate fertilizers, and watering practices in agricultural lands. The use of wastewater from the city in agriculture irrigation may have significant effects of accumulation of toxic heavy metals in soils and agricultural products. The use of waste water from the city in agriculture irrigation may have significant effects of accumulation of heavy metals in soils and agricultural products (Singh *et al*., 2010; Naaz & Pandey, 2010; Cu, 2015). These toxic heavy metals transferred and concentrated into plant tissues from the soil due to absorption that commonly occurs in the root system, where it is in direct contact with pollutants. Toxic heavy metals have damaging effects on the plants and become a health hazard to man and animals. Above certain concentrations the toxic heavy metals turn into toxins and affect natural microbial populations, leading to disruption of vital ecological processes (Sterritt & Lester, 1980; Brynhildsen & Rosswall, 1997). Effects of toxic heavy metals on the growth of plants and microorganisms have been investigated by several researchers (Cu, 2015; Nazar *et al*., 2012, Aydinalp & Marinova, 2009; Mahmood *et al*., 2007; Fayiga *et al*., 2004; Rout & Das, 2003; Baccouch *et al*., 1998; Coppola *et al*., 1988). Scanning electron microscopy (SEM) and energy-dispersive X-ray spectroscopy (EDS) were used to determine toxic heavy metals in plants tissues (Psaras & Manetas, 2001; Qi *et al*., 2003; Arru *et al*., 2004; Yashvanth *et al*., 2013; Galvez *et al*., 2015).

The importance of sulfur as a soil conditioner in reducing the sodium content, and nitrogen fixing, necessary in the formation of proteins, amino acids, enzymes, vitamins, and chlorophyll, and helps the plant's resistance to disease lead the authors to study the effect of sulfur nanoparticles (SNPs) on plant growth (Salem et al., 2016). As continuation of our previous work, Scanning electron microscopy (SEM) equipped with energy-dispersive X-ray spectroscopy (EDS) and Atomic absorption spectroscopy (AAS) were used for determination the toxic heavy metals in irrigation water, soil, roots, stems, leaves, and fruits of tomato.

MATERIALS AND METHODS

Tomato seeds (*Solanum lycopersicum*) were planted in the Faculty of Agriculture, the University of Jordan green house and grown in pots. Tomato planted within the greenhouse were grown in optimal conditions. After two weeks, plants were picked out and transferred to a field at the Royal Scientific Society, where they grow in soil of the field. Sulfur nanoparticles (SNPs) were applied to the field soil 300 ppm doses to produce healthy plants (salem et al., 2016). In order to accomplish the objectives of this work, The roots, stems, leaves, and fruits of tomato plants were collected, washed with distilled water and dried in an oven at 60ºC for 24h. Scanning electron microscopy equipped with energy-dispersive X-ray spectroscopy (Quanta FEI 450 SEM machine) was used to determine atomic weigth percent of toxic heavy metals in the tissues of tomato plant. Water of irigation and the soil were analysed by Shimadzu AAS6300 atomic absorption spectrometer.

RESULTS AND DISCUSSIONS

Scanning electron microscopy (SEM) images of roots, stems, leaves, and fruits of tomato were recorded, Figure-1. The images were observed under SEM at 1000x magnification. SEM images depicts crystals of various shapes, root a cluster of spherical shaped crystals, sheet shaped crystals in stem, leaves inclusion in leaves, and spherical crystals in shape in fruits.

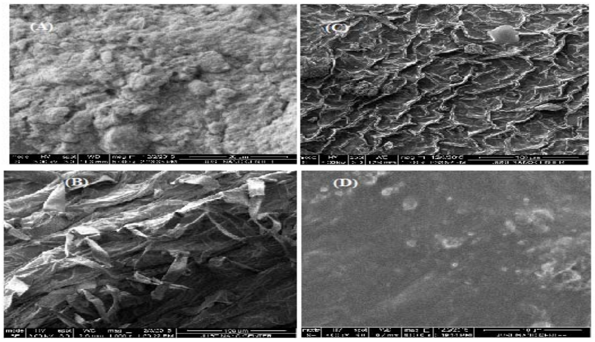

Figure-1. SEM image of (A) roots, (B) stems, (C) leaves and (D) fruits.

Atomic absorption (AAS) analysis of irrigation water and the soil used in the field for growing tomato plants is presented in Table-1. The major elements found in irrigation water and in the soil are iron (Fe), magnesium (Mg), and calcium (Ca), where toxic heavy metals were found as traces. Hg^{2+} was not detected in irrigation water, soil, and plant parts.

Table-1. Elemental analysis concentrations (ppm) of irrigation water and soil used for growing tomato plants.

Metal	Irrigation water	Soil
Zn	BDL	8
Cu	12	44
Cr	BDL	23
Pb	6	18
Cd	BDL	BDL
Mn	BDL	15
Fe	14554	44866
Na	226	184
Ca	6543	13568
Mg	7423	4665

The elemental analysis of all tomato plant parts by SEM-EDS is presented in Table-2. A sample of EDS analysis for roots and fruits of tomato are illustrated in Figures 2 and 3. The contimation of the roots tissue with traces of toxic heavy metal zinc (Zn^{2+}), titanium (Ti^{4+}), Mangnese (Mn^{2+}), cobalt (Co^{2+}), Copper (Cu^{2+}), lead (Pb^{2+}) and chromium (Cr^{3+},Cr^{6+}). These traces were accumulated and absorbed by roots from the water and/or the soil and no indication transfered to the stems, leaves and fruits of tomato. Pb^{2+} and Cu^{2+} as toxic heavy metals moved from the root to stem and not detected in leaves, and fruits. A one way analysis of variance was performed for the analysis of differences in weigth percent (Wt.%) mean elements concentration among parts of tomato plant using a 5% probability level. Table-2 of elemental analysis concentration (ppm) of roots, stems, leaves, and fruits showed significant differences.

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Table-2. Elemental analysis concentration (ppm) of roots, stems, leaves, and fruits of tomato by SEM-EDS.

Elements	Roots	Stems	Leaves	Fruits
Na	3700	4000	3600	1100
Mg	3800	2700	6500	3400
Al	13000	3600	3800	1900
Si	26100	4700	1000	3600
P	BDL	1500	3300	2600
S	4400	4300	13600	1500
Cl	14100	23000	11700	1600
K	11900	22800	740	15400
Ca	14800	21700	38700	BDL
Fe	4600	2300	2600	900
Pb	700	850	BDL	BDL
Co	15	BDL	BDL	BDL
Cr	12	BDL	BDL	BDL
Mn	180	BDL	BDL	BDL
Ti	1700	BDL	BDL	BDL
Zn	2700	BDL	BDL	BDL
Cu	1800	14	BDL	BDL

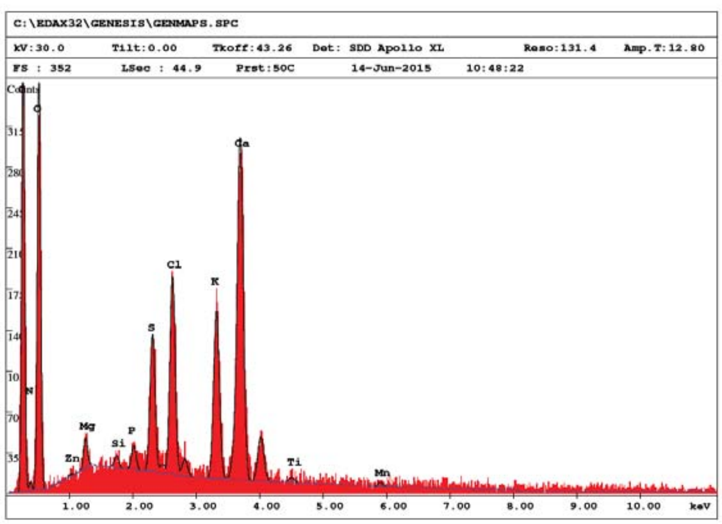

Figure-2. EDS analysis roots of tomato.

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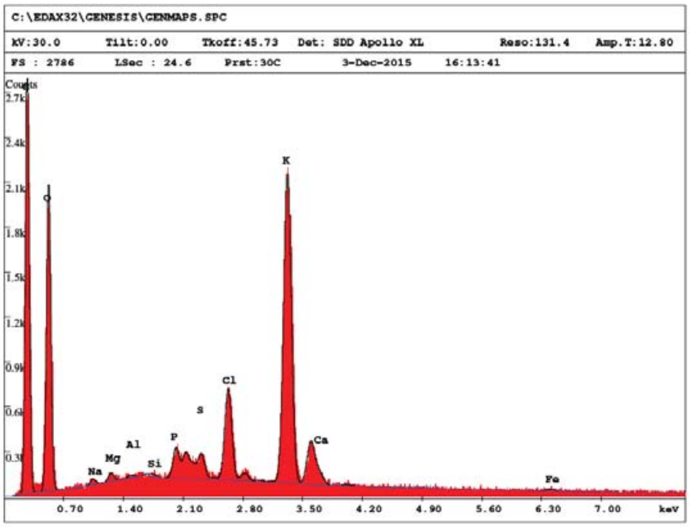

Figure-3. EDS analysis fruits of tomato.

Figure-4 shows the average toxic heavy metal concentrations (ppm) in the roots, stems, leaves, and fruits of tomato plant. These toxic heavy metals are in contact with the plant from water and the soil and mostly accumulated in the the root system. Figure-4 illustrated that most of these toxic heavy metal are concentrated in the roots system. Fe was found to be accumulated in all parts of tomato plant

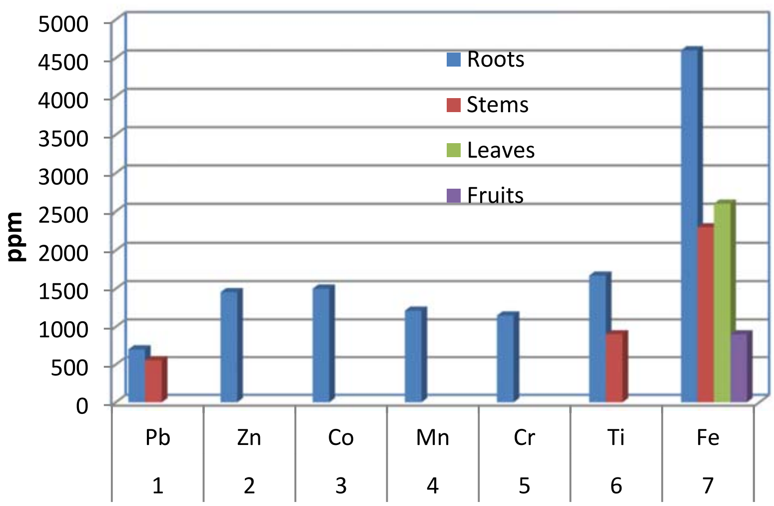

Figure-4 shows the average toxic heavy metals detected by SEM-EDS in the roots, stems, leaves, and fruits of tomato.

Figure-5 shows the average metals Na, K, Mg, Ca, Al, Si, P, Cl, and S in roots, stems, leaves, and fruits of tomato. The highest concentration (ppm) of Ca accumulated in the stems and leaves; Si in roots; K, and Cl in stems; K in fruits; S in leaves; P has the lowest concentration in stems, leaves, and fruits.

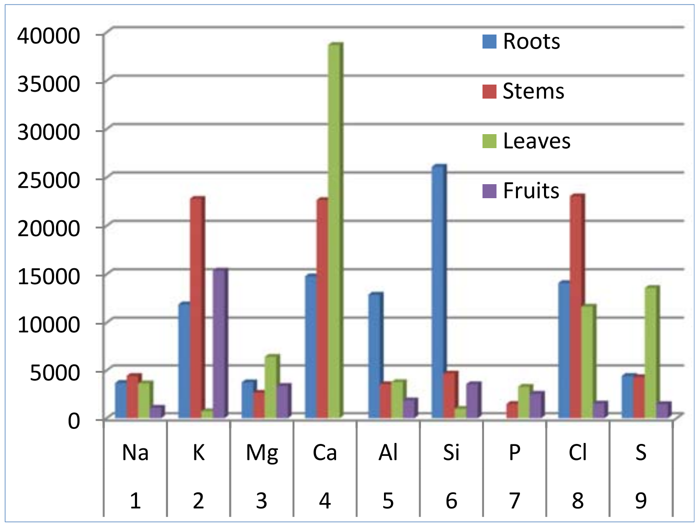

Figure-5 shows the average non-toxic metals detected by SEM-EDS in the roots, stems, leaves, and fruits of tomato.

CONCLUSIONS

In the present study, toxic heavy metals (Zn, Cu, Cd, Hg, Co, Mn, Cr) were detected in irrigation water, soil, roots, stems, leaves, and fruits of tomato using atomic absorption spectroscopy (AAS) and scanning electron microscopy-energy dispersive X-ray spectroscopy (SEM-EDS) techniques. All irrigation water samples were found to contain elements such as Cu, Pb, Fe, Na, K, Ca, and Mg. Elements of Zn, Cu, Cr, Pb, Mn, Fe, Na, Ca, and Mg detected in soil. Results of elemental analysis using EDS showed that the toxic heavy metals Fe, Pb, Co, Cr, Mn, Ti, Zn, and Cu are accumulated in the roots of tomato plants. The most hazardous toxic heavy metal Pb was found to be the only metal could accumulate in roots and transferred to stems of tomato. No toxic heavy metal could be traced in fruits of tomato

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REFERENCES

Arru L., Rognoni S., Baroncini M., Bonatti P. M., Perata P. 2004. Copper localization in *Cannabis sativa L*. grown in a copper-rich solution.Euphytica140: 33–38.

Aydinalp C., Marinova S.2009. The effects of heavy metals on seed germination and plant growth on Alfalfa plant (*Medicago sativa*). Bulgarian J. Agri. Sci. 15: 347-350.

Baccouch S., Chaovi A., El Ferjani E. 1998. Nickel toxicity: effects on growth and metabolism of maize. J. Plant.Nutr.21: 577-588.

Brynhildsen L., Rosswall T. 1997. Effects of metals on the microbial mineralization of organic acids. Water, Air, and Soil Pollut. 94: 45–57.

Coppola S., Dumontet S., Portonio M., Basile G., Marino P. 1988. Effect of cadmium bearing sewage sludge on crop plants and microorganisms in two different soils. Agric. Ecosyst. Environ. 20:181-194.

Fayigaa A.O., Maa L. Q., Caoa X., Rathinasabapathi B. 2004. Effects of heavy metals on growth and arsenic accumulation in the arsenic hyper accumulator Pterisvittata L. Environ.Pollut.132: 289-296.

Galvez M. C., De Guzman J. F., Gueco S. D., Camelo J., Castilla R., Edgar A., Vallar E. A. 2015. SEM/EDX analysis of the roots of water *Eichorniacrassipes* collected along Pasig River Manila A, Philippines. ARPN J. Agri. and Biol. Sci. 10: 458-463.

Mahmood T., Islam K. R., Muhammad S. 2007. Toxic effects of heavy metals on growth and tolerance of cereal crops. Pak. J. Bot. 39: 451-462.

Naaz S., Pandey S. N. 2010. Effects of industrial waste water on heavy metal accumulation, growth and biochemical responses of lettuce (*Lactuca sativa* L.). J. Environ. Biol. Growth. 31: 273-276.

Nazar R., Iqbal N., Masood A., Iqbal M., Khan R., Syeed S., Khan N. A. 2012. Cadmium toxicity in plants and role of mineral nutrients in its alleviation. Amer. J. Plant Sci. 3:1476-1489.

Cu N. X. 2015. The effects of heavy metals, phosphate, lime and sawdust on plant growth and heavy metal accumulation by lettuce. ARPN J. Agri. and Biol. Sci. 10: 241-246.

Psaras G. K., Manetas Y. 2001. Nickel localization in seeds of the metal hyperaccumulator *Thlaspipindicum Hausskn*. Annals of Botany. 88: 513-516.

Qi Y., Lian K.,Chin K. L., Ford R. 2003. Using EDX/SEM to study heavy metal uptake and elemental composition in plant tissues. Microscopy and Microanalysis. 9: 1486-1487

Rout G. R., Das P. 2003. Effect of metal toxicity on plant growth and metabolism: I. Zinc. Agronomie. 23: 3–11.

Salem N. M., Albanna L. S., Awwad A. M., Abdeen A. O., Ibrahim Q. I. 2016. Sulfur nanoparticles improves root and shoot growth of tomato. J. agri. Sci. 8: 179-185.

Singh A., Rajeshkumar S.,Madhoolika A., Fiona M. 2010. Risk management of heavy metal toxicity through contaminated vegetables from wastewater irrigated area of varanasi, India. Tropical Ecology. 51: 375-387.

Sterritt R. M., Lester J. N. 1980. Interactions of heavy metals with bacteria. Sci. Tot. Environ. 14: 5-17.

Yashvanth S., Rani S. S., Madhavendra S. S. 2013. Micro chemical (elemental) analysis of *Leucasaspera* (Willd) link employing SEM-EDAX. Inter. J. Pharm. Sci. and Drug Res. 5: 32-35.