Journal of Environment and Earth Science
ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online)
Vol. 3, No.1, 2013

The Role of Maize Tassels in Amelioration of Heavy Metals from Contaminated Soils and its Effects on Vegetables.

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Abstract

Vegetables depend on water as solvent for their growth and have greater potential of accumulating in their edible parts heavy metals which are dangerous to human health. Maize tassel was applied to soil to determine its role in removal of heavy metals such as Manganese (Mn), Iron (Fe), Cadmium (Cd) and Zinc (Zn) from the contaminated soil with cabbage as the test crop. The average mean concentration of the heavy metals after twenty one and fifty one days were; Mn (0.402 mg/kg and 7.427 mg/kg), Fe (0.894 mg/kg and 4.838 mg/kg) and Zn (0.155 mg/kg and 1.073 mg/kg) respectively. The concentration of cadmium in the wastewater sample used was 0.680mg/l, and its concentrations in tap water (<0.002mg/l), in soil (<0.002mg/kg) were below the detection limit. The enrichment factor for Mn, Fe and Zn in soil treated with maize tassel (T1) are 9.73, 10.70 and 5.23 respectively, whereas treatment without (T2) are 1.05, 1.86 and 4.52 respectively. The high enrichment of T1 is attributed to the availability of the active site within the tassel absorbent.

Keywords: Heavy metals, maize tassel, contaminated soil, wastewater.

1. Introduction

Heavy metal contamination of soil and water may pose risk to humans and the ecosystem through direct ingestion or contact with contaminated soil and water. Excessive release of heavy metals into the environment due to industrialization and urbanization has posed a great problem worldwide. Heavy metal toxicity can result in reduced mental and central nervous function, lower energy levels and damage to blood composition, lungs, kidneys and other vital organs (Amarasinghe, and Williams, 2007). Some of the metals associated with these activities are cadmium (Cd), manganese (Mn), zinc (Zn) and iron (Fe).

Maize tassel is the male part of the maize plant. Its major purpose is the production of pollen grains which fertilize the female part of the maize flower which then develops into a cob. Maize is capable of continuous phytoextration of metals from contaminated soils by translocating them from roots to shoots (Nascimento and Xing, 2006). The ability of biological materials to adsorb metal irons has received considerable attention for the development of efficient, clean and cheap technology for wastewater treatment at metal concentrations as low as 1 mg/l (Salt et al, 1995). Interestingly, there are also increased evidences that show phytoextration as a viable technology for the removal of potentially toxic metals from soil (Baker *et al*, 1994; McGrath *et al*, 2001; Maxted *et al.*, 2007). The potential use of this robust tropical crop in phytoextration technology is advocated especially for developing countries with scarce funds available for environmental restoration (Wuana and Okieimen, 2010).

A plant for phytoremediation is expected to be heavy metal tolerant, grow rapidly with a high biomass yield per hectare, high metal accumulating ability in the foliar parts, a profuse root system, and a high bioaccumulation factor (Scragg, 2006; Jadia and Fulekar, 2008). Maize tassel are able to remove significant amount of metals to a level within the permissible guideline values for arsenic, lead, mercury and manganese in drinking water (Dzifa, 2011; Dzifa *et al.,* 2012).

Leafy vegetables have greater potentials of accumulating heavy metals in their edible parts than grain or fruit crops (Anjula A. et al, 2011). Studies on uptake of heavy metals by plants have shown that heavy metals can be transported passively from roots to shoots through the xylem vessel (Kirkham, 1977; Krijger *et al*., 1999). The technology of using maize tassel in amelioration is effective in contaminant reduction, low-cost, and being applicable for wide range of contaminants (Dzifa, 2011; Dzifa *et al.,* 2012). The role of maize tassel in ameliorating heavy metals from contaminated soil and its effects on vegetable was done using mining

wastewater and cabbage *(Brassica Oleracea var capitata)* as test crop.

2. **Materials and Methods**

2.1 Study area

The study was conducted at the plant house of the University for Development Studies, Nyankpala campus in the Tolon Kumbungu District near Tamale Metropolis in the Northern region of Ghana. The plant house is located between latitude 09 25` 41``N and longitude 0^0 58`42W with altitude of 183 m(msL).The study area received mean precipitation of 78.13 mm within the four month period of experiment. The mean temperature distribution during the period was 27.9^{0}C with the mean relative humidity of 68.25 %.

2.2 Experimental Set-up

The study was carried out using plastic pots. The soil sample used for the treatments was taken from Nyankpala greenhouse of University of Development studies. It was sieved and later used to nurse the seeds with a ratio of two parts of sandy loam to one part of river sand. The sieved soil was filled in 24 cm × 27.2 cm plastic containers at the ratio of two part of sandy loam to one part of grinded maize tassel with 126.98 g or 0.127 Kg of river sand to avoid water logging. Drainage holes were created at the bottom of each pot for free drainage of excess water in order to avoid water logging.

The pots filled with soil were irrigated with wastewater (polluted water) from the mining site with known heavy metal concentration until the plants matured. Also, the pot irrigated with tap water (unpolluted water) of known heavy metal concentration serves as control.

The set-up comprised of four treatments each replicated three times. The containers were arranged on the platforms using the completely randomized block design. Treatments were as follows; T1, T2, T3, and T4

The media was one part of sandy loamy soil mixed with one part of grinded Okomasa maize tassel of which cabbage *(Brassica Oleracea var capitata) variety Oxylu*s was used as the test crop for the experiment.

2.3 Field Sampling

Wastewater from a mining site at Kenyasi in the Brong Ahafo Region of Ghana was used for watering the test crop. pH of the waste water were measured *in situ* using portable pH meter. Samples for the physico-chemical analysis were collected into 1 L clean plastic bottles and that for watering of the test crop were always carried in acid- washed 20 litres polypropylene container throughout the project.

2.4 Analysis of soil, water and test crop samples

2.4.1 Digestion of soil sample for analysis

The soil samples were analysed in the laboratory for heavy metals (cadmium, zinc, iron and manganese) with the aid of Shimadzu Atomic Absorption Spectrophotometer (model AA-6300).

Procedure for examination of trace metals in the soil sample was adopted from European standard ISO/TS 21268-1. The soil pH was determined using 0.01M $CaCl_2$ with the aid of the end-over-end shaker and centrifuge model CENTRO-8. The soil sample extraction with 0.01 M $CaCl_2$ was done by measuring 30 g of soil sample into an acid-washed 100ml polypropylene bottle with the addition of 60 ml of $CaCl_2$ solution and attached to end-over-end shaker to shake vigorously for 24-hours. The suspensions were allowed to settle for a maximum of 24-hours for pH determination on the subsample. The rest of the supernatant solution filtered. The geochemically active concentration of trace metals in the soil samples were initially extracted using 0.1 M of HNO_3. The 0.1M HNO_3 extraction was done using 2.0 g of soil sample with the addition of 35 ml of HNO_3 solution and attached to end-over-end shaker to shake for 16-hours, after which the digested sample was subjected to centrifuge at high speed and filtration. The supernatant was decanted into the scintillation bottles for analysis. The analysis of the heavy metals was done using the Shimadzu atomic absorption spectrophotometer (model AA-6300).

2.4.2 Analysis of water sample

The metals analysis in the contaminated water and tap water followed the procedure described in the

standard methods for examination of water and wastewater (APHA 1998). The water samples were acidify to a pH< 2 by adding 2 mL conc. HNO_3/L and analysed directly with the aid of AAS as described.

2.4.3 Digestion of the test crop for analysis.

The test crop was harvested and analysed after 21 and 51 days of treatments T1, T2, T3, and T4 set-up. The different parts (stem, leaves and roots) of the test crop were rinsed with de-ionised water, weighed, oven dried at 105 ^{0}C for 3 hours and grinded into powder. The powdered test plant samples were digested using 0.8 ml of HNO_3 for the metal analysis.

3. Results and Discussion

3.1 Concentration of heavy metals in soil and water sample

The results indicated that the concentration of Mn, Fe, Zn and Cd in the wastewater used for the experiment were above the WHO permissible limits. However, their concentration in tap water were below the WHO recommended limits hence tap water described as unpolluted water in this project with respect to the selected metals analysed. The concentrations of manganese, iron, zinc and cadmium are shown in the Table 1 below. The mean pH of 6.57 of the soil sample, 7.05 for tap water and 5.74 for the polluted water were determined using pH meter.

Table 1: Mean Concentration of Heavy Metals in Raw Samples used for the Experiment

Sample	Mn	Fe	Zn	Cd
Tap Water	<0.005	<0.01	<0.01	<0.002
Waste Water	0.763	0.452	0.205	0.680
Soil (mg/kg)	62.170	26.740	0.856	<0.002
WHO Limit	**0.5 (p)**	**0.3**	**5.0**	**0.003**

All units are in mg/l unless otherwise stated. Where < = below detection limits

3.2 Heavy metals accumulation after 21 days of transplanting

Manganese generally recorded a varied level of accumulation after transplanting of the test crop in treatment one with Okomasa maize tassel. The Okomasa maize tassel on the average adsorbed high manganese as compared to the rest of the treatments ranging from 0.326 mg/kg to 0.515 mg/kg. This observed trend of accumulation of manganese by Okomasa maize variety in treatment one may be attributed to the presence of multiple adsorption sites for manganese adsorption on Okomasa maize tassel (Dzifa, 2011). Iron recorded varied levels of accumulation at 21 days of transplanting of the test crop ranging from 0.074 mg/kg to 1.203 mg/kg. The rapid adsorption and removal of iron by Okomasa maize tassel indicated a high affinity of available surface groups on maize tassel for iron. The highest value of accumulation and removal of iron was observed in the leaf and root of the test crop.

The accumulation of cadmium at 21 days after transplanting was found to be below detection level of <0.002 mg/kg. However, Okomasa maize tassel has the ability to remove cadmium (Dzifa, 2011); the inability of the *Brassica Oleracea var capitata* to absorb Cd in all the treatment can be as a result of high affinity of *Brassica Oleracea var capitata* for Mn, Fe, and Zn. The leaves of treatment one was observed to record the highest accumulation value of 0.155 mg/kg of zinc at 21 days after transplanting. The observed increased in the adsorption of heavy metals in treatment one can be attributed to the availability of the active site within the tassel absorbent (Zvinowanda *et al.,* 2009). The mean metal concentrations for Mn, Fe, Zn and Cd after 21 day of transplanting are shown in Table 2. and figure 1.

Table 2. Overall Mean Concentration (mg/kg) of Heavy Metals in Cabbage after 21 days.

Treatment		Mn	Fe	Zn	Cd
T1	Root	0.365	0.849	0.1	<0.002
	Stem	0.326	0.633	0.035	<0.002
	Leaves	0.515	1.203	0.33	<0.002
	Overall	0.4	0.89	0.16	0.001
	Mean (± SD)	(± 0.1)	(± 0.29)	(±0.16)	(± 0.0)
T2	Roots	<0.005	0.239	<0.01	<0.002
	Stem	<0.005	0.982	<0.01	<0.002
	Leaves	<0.005	0.797	<0.01	<0.002
	Overall	0.194	0.673	0.011	0.001
	Mean (± SD)	(± 0.32)	(± 0.39)	(±0.02)	(± 0.0)
T3	Root	<0.005	0.074	<0.01	<0.002
	Stem	<0.005	0.121	<0.01	<0.002
	Leaves	<0.005	0.172	0.111	<0.002
	Overall	0.05	0.122	0.038	0.001
	Mean (± SD)	(± 0.0)	(± 0.05)	(±0.06)	(± 0.0)
T4	Roots	0.044	0.274	0.046	<0.002
	Stem	0.038	0.249	0.09	<0.002
	Leaves	<0.005	0.172	0.267	<0.002
	Overall	0.028	0.232	0.134	0.001
	Mean (± SD)	(± 0.02)	(± 0.05)	(±0.11)	(± 0.0)

All units are in mg/kg dried weight unless otherwise stated, Where <= below detection limits,
SD = standard deviation, T1= maize tassel + polluted water + soil,
T2= polluted water + soil, T3= maize tassel + unpolluted water + soil,
T4= unpolluted water + soil.

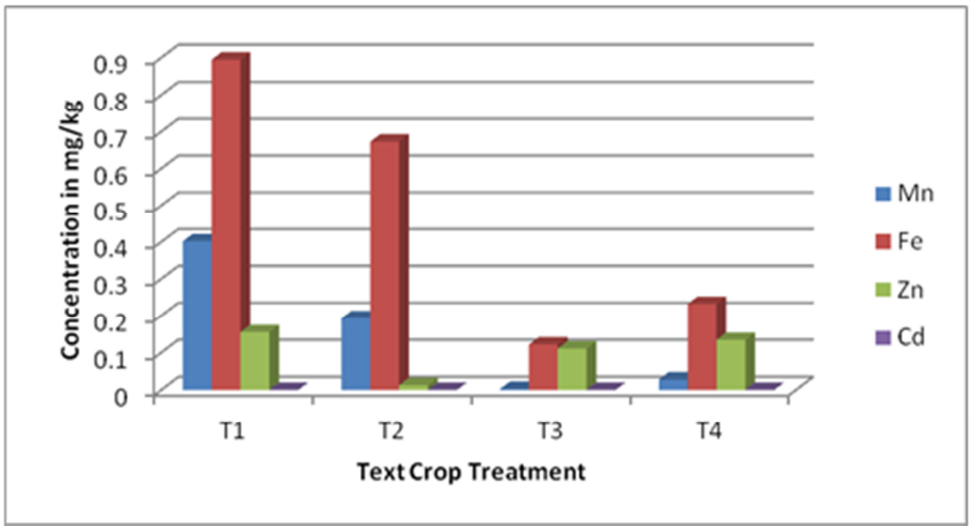

Figure 1. Mean Concentration of Heavy metals in text crop after 21 days

3.3 Heavy metals accumulation after 51 days of transplanting

Manganese recorded a varied level of accumulation at 51 days after transplanting of the test crop in treatment one with Okomasa maize tassel ranging from 0.892 mg/kg to 16.64 mg/kg. The treatment one with Okomasa maize tassel on the average adsorbed high manganese at 51 days after transplanting as compared to the rest of the treatments. The iron levels of accumulation at 51 days after transplanting ranges from 0.484 mg/kg to 13.33 mg/kg dried weight. The rapid adsorption and removal of iron by Okomasa maize tassel as indicated above

is as result of high affinity of available surface groups on maize tassel for iron as evident in the leaf and root of the test crop at 51 days after transplanting (see table3 and fig2).

The level of cadmium at 51 days was found to be below detection level (<0.002 mg/kg) as evident in the raw soil samples. The treatment one was observed to record the highest average mean accumulation value of 1.073mg/kg of zinc due to the availability of the active site within the tassel absorbent (Zvinowanda *et al.,* 2009). These reaffirm the levels of heavy metals bioaccumulation from 21days of transplanting (Table 2 and 3).

Table 3: Overall Mean Concentration of Heavy Metals in Cabbage after 51 days of Transplanting

Treatment		Mn	Fe	Zn	Cd
	Roots	16.64	13.33	0.589	<0.002
T1	Stem	0.892	0.515	1.748	<0.002
	Leaves	4.748	0.669	0.881	<0.002
	Overall	**7.427**	**4.838**	**1.073**	**0.001**
	Mean (± SD)	(± 8.21)	(± 7.35)	(±0.6)	(± 0.0)
	Roots	0.25	0.484	0.891	<0.002
T2	Stem	0.303	0.515	0.615	<0.002
	Leaves	0.852	1.517	1.271	<0.002
	Overall	**0.802**	**0.839**	**0.926**	**0.001**
	Mean (± SD)	(± 0.91)	(± 0.59)	(±0.33)	(± 0.0)
	Roots	3.442	4.607	0.718	<0.002
T3	Stem	1.125	0.666	1.072	<0.002
	Leaves	1.139	0.677	1.085	<0.002
	Overall	**1.902**	**1.938**	**0.958**	**0.001**
	Mean (± SD)	(± 1.33)	(± 2.27)	(±0.21)	(± 0.0)
	Roots	0.316	0.774	0.396	<0.002
T4	Stem	0.263	0.572	0.46	<0.002
	Leaves	1.014	1.83	1.588	<0.002
	Overall	**0.531**	**1.059**	**0.815**	**0.001**
	Mean (± SD)	(± 0.42)	(± 0.68)	(±0.67)	(± 0.0)

All units are in mg/kg dried weight unless otherwise stated, Where < = below detection limits.

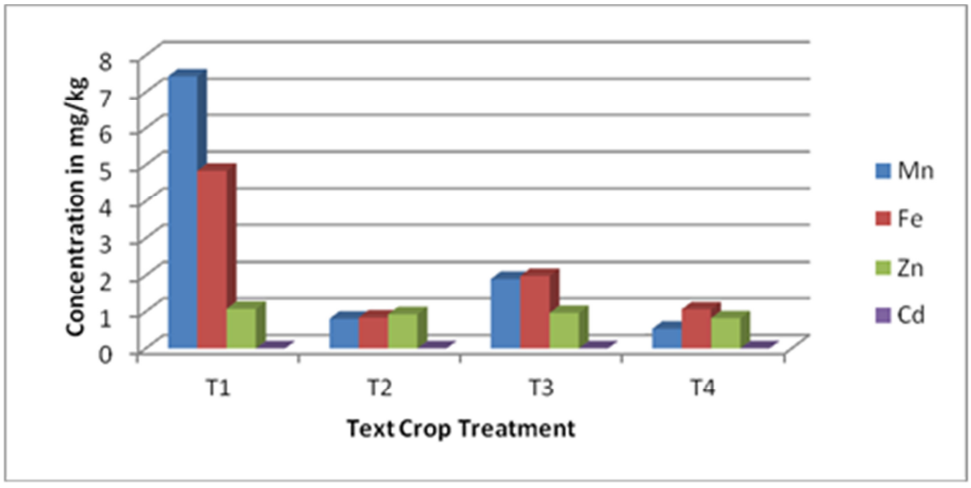

Figure 2. Mean Concentration of Heavy metals in text crop after 51 days

3.4 Transfer Factor (TF)

The transfer factor is the ratio of heavy metals concentration in the test crop to the total metal concentration in

the soil used. It also signifies the amount of heavy metals in the soil that ended up in the test crop (Samuel, N. O., et al 2008) as in Table 4 below.

Table 4: Transfer Factor (TF) of Some Heavy Metals in Cabbage after 51 days.

Treatment		Mn	Fe	Zn	Cd
	Root	0.268	0.499	0.688	-*
T1	Stem	0.014	0.019	2.042	-
	Leaves	0.076	0.025	1.022	-
	Roots	0.004	0.018	1.071	-
T2	Stem	0.005	0.009	0.718	-
	Leaves	0.014	0.057	1.485	-
	Root	0.055	0.172	0.839	-
T3	Stem	0.018	0.025	1.252	-
	Leaves	0.018	0.025	1.268	-
	Roots	0.005	0.029	0.463	-
T4	Stem	0.004	0.021	0.537	-
	Leaves	0.016	0.068	1.855	-

Where -* = below detection limits

From the results in Table 4, treatment one recorded high levels of heavy metals than the rest after transplanting and again, the roots and leaves contain high TF.

3.5 Enrichment Coefficient and Translocation Factor

The enrichment coefficient can also be used to evaluate the ability of the cabbage plant to accumulate heavy metals (Y. Lou et al, 2012). It is the ratio of metal concentration in plants to the metal concentration in the solution (wastewater, in this case). With the exception of Cd, the enrichment factor for Mn, Fe and Zn in treatment T1 were 9.73, 10.70 and 5.23 respectively, whereas that of treatment T2 were 1.05, 1.86 and 4.52. The high enrichment of T1 can be attributed to the presence of maize tassel. The translocation factor on the other hand, indicates preferential partitioning of metal to shoots and plants with higher translocation factor have greater accumulation ability (Y. lou et al, 2012). The translocation factors presented in Table 5, below followed Y. lou et al (2012) methods of calculation. Thus, ratio of metal concentration in plants leaves to metal concentration in the plant's root. With exception of Cd which was below detection limit (<0.002 mg/kg), almost all the four treatments accumulated the Mn, Fe, and Zn in the leaves ranging from 1.426 to 4.010. This observation confirms the study by Anjula A. et al, (2011), that leafy vegetables have greater potentials of accumulating heavy metals in their edible parts. Maize tassel treated soils was observed to retained Mn and Fe in the roots of *Brassica Oleracea var capitata* contrary to expectation.

Table 5: Translocation Factor of some Heavy Metals in Cabbage after 51 days.

Treatment	Mn	Fe	Zn	Cd
T1	0.285	0.050	1.496	-*
T2	3.408	3.134	1.426	-
T3	0.331	0.147	1.511	-
T4	3.209	2.364	4.010	-

Where -* = below detection limits

The overall results showed that samples treated with maize tassels accumulated high concentrations of the Mn, Fe and Zn than those with tap water and natural soil only.

4. Conclusion

The study reveals that maize tassel treated soil (T1) facilitates the bioaccumulation of heavy metals in cabbage as compared to treatments without the maize tassel. The maize tassel has the potentials of remediating contaminated soil. The enrichment factor for Mn, Fe and Zn in treatment T1 were 9.73, 10.70 and 5.23 respectively, whereas that of treatment T2 were 1.05, 1.86 and 4.52. The high enrichment of T1 can be attributed to the maize tassel multiple adsorption site.

5. Recommendation

Based on the results, the maize tassel has the potentials of ameliorating contaminated soils and it is therefore recommended as a means of phytoremediation.

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