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PHYTOREMEDIATION OF HEAVY METALS POLLUTED SOIL USING SUDAN GRASS

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ABSTRACT

A pot experiment was conducted at the farm of Faculty of Agric., Al-Azhar University, Nasr City, Cairo, Egypt during the summer season of 2010 to evaluate the effect of phytoextraction involves the use of Sudan grass (*Sorghum vulgare var sudanense)* plant to remove some heavy metals from the soil. Surface soil samples (0-30cm) were collected from El-Gable El-Asfer farm located 25km northeast Cairo, Egypt. The experiment involved 21 pots comprised 7 treatments in three replicates in a completely randomized design. The soil was mixed with materials, added as amendments, *i.e.* compost (5 ton fed^{-1}), pure sulfur 98.5(2 ton fed^{-1}) and gypsum (3 ton fed^{-1}) before planting. The results could be summarized as follows;

1- Sudan grass has a high ability to accumulate heavy metals specially, Zn, Cu and Pb in harvestable plant tissues. Also, Sudan grass could be considered as a hyper accumulator plant to these metals. Thus, Sudan grass may be used successfully to clean soils polluted with heavy metals specially Zn, Cu and Pb, 2- The important use of compost, sulfur and gypsum to reduce soil reaction (pH) increase the soluble amount of Zn, Cu, Mn and Pb available to plant and 3-The phytoremediation of the soil could be recommended as an environmentally safe and cheep method for the remediation of the heavy metal polluted soil in Egypt.

Key words: *hyper accumulator , phytoremediation, polluted soil , Sudan grass.*

1.INTRODUCTION

Heavy metal contamination of soils has increased significantly in the last years owing to anthropic action. Several techniques can be used to pervert or to minimize soil contamination, although many of these techniques are harmful to the soil. An alternative is to use a new technique, called phytoremediation, based on the ability of plants to take up elements from the soils with excessive high levels of metals or other potentially toxic elements that contribute to soil decontamination (Souza, 2011). Revathi, *et al.* (2011) studied Phytoremediation of Chromium contaminated soil using Sorghum plants. The results indicated that there was a significant reduction of biomass of the plant with increased the dosage of chromium. It is also observed that Phytoremediation is found to be cost-effective and highly efficient in remediating the heavy metal polluted sites. The phytoremediation efficiency of field crops is rarely high, but their great growth potential compared with hyper accumulators should be considered positively, so that they can establish a dense green canopy in polluted soil (Vamerali, *et al.* 2010).

Zhuang, *et al.* (2009) stated that the application of ammonium nitrate and ammonium sulfate increased the accumulation of both Zn and Cd in roots of sorghum plants; suggesting that cropping of sorghum plants facilitated by agronomic practices may be a sustainable technique for partial decontamination of heavy metal contaminated soils. Also, Jadia and Fulekar (2008) indicated that, Vermicompost from vegetable waste has high nutrient contents and therefore, it can be used as a natural fertilizer to increase growth of plants that play a role in phytoremediation. Kalpana and Satyawati (2009) studied the effect of Arbuscular Mycorrhizal (AM) colonization on the uptake of cadmium (Cd) from artificially contaminated soil. Soil pH was significantly lower in non-AM than AM treatments at the highest soil-Cd. The results indicated possible exploitation of AM colonization for better metal accumulation in plant for phytoremediation purpose. Hattori, *et al.* (2006) showed that the application of low pH treatment increased Cd uptake in all the studied plant species and that could be a promising method for phytoremediation of Cd in combination with soil pH adjustment, depending on the tolerance of the plant species to low pH. Xu, *et al.* (2007) showed that lead accumulation in the shoots of the plants exposed to EDTA-pb at 1:1 ratio was only one-fifth of that exposed to ionic Pb at the same concentration. Marchiol, *et al.* (2007) indicated that, the metal removal was calculated for the harvestable parts of the crops. The amelioration of the nutritive status of the substrate that resulted was highly effective for the biomass yield. However, fertilization and soil amendment did not increase the concentration of metals in the harvestable tissue of the plants during the crop cycle.

The evaluation of potential of phytoremediation plants compared to other crops in terms of metal removal was positive. These results of metal removal are consistent with the results other *in situ* experiments. This study was undertaken to evaluate the effect of phytoremediation as a tool for the remediation of some heavy metals polluted soil using Sudan grass.

2. MATERIALS AND METHODS

A pot experiment was conducted at the farm of the Faculty of Agric., Al-Azhar University, Nasr City, Cairo, Egypt during the summer season of 2010. Surface soil samples (0-30cm)were collected from El-Gable El-Asfer farm located at 25km northeast Cairo, Egypt, This soil is irrigated continuously with sewage effluent for about 80 years, to study the effect of phytoextraction involves the use of Sudan grass (*Sorghum vulgare var sudanense)* to remove some heavy metals from the contaminated soil. The experiment involved 21 pots comprised 7 treatments in three replicates in distributed completely randomized design (Snedecor and Cochram, 1972). The soil was mixed with three materials added as amendments, *i.e.* compost (5 ton/fed), pure sulfur 98.5 ELAHRAM COMPANY production (2 ton/fed) and Gypsum (3 ton/fed) before planting. Seven treatments were used as follows;

1- Polluted soil (Control).
2- Polluted soil + Compost
3- Polluted soil + Sulfur
4- Polluted soil + Gypsum
5- Polluted soil + Compost + Sulfur
6- Polluted soil + Compost + Gypsum
7- Polluted soil + Compost + Sulfur + Gypsum

The NPK fertilizers were applied according to the recommended rates, ammonium sulfate (100kg/Fed), super phosphate (150 kg/Fed) and K- sulfate (50 kg/Fed). A pot of 30 cm diameter and 35 cm depth was filled by 10kg of sandy loam soil. Three seedlings of Sudan grass were planted in each pot. The moisture content of soil was kept at field capacity along the period of experiment. Three cuts were collected from the plants in a period of four months from planting. The first one was collected after 8 weeks from planting, the second one after 13 weeks from seedling and the third one after 18 weeks from seedling. The plants were cut 1 cm above the soil surface. At the end of the experiment the plants were harvested and prepared for analysis. The characteristics of the investigated soil (particle size distribution, was determined according to Klute, 1986) and chemical properties(*i.e.* EC, pH, organic matter, soluble cations, and soluble anions according to Page *et al.,* 1982) to detect the changes that might take place in soil characteristics. The plant samples were ground and wet digested with acids mixture (HNO_3 and $HClO_4$) according to Jackson (1973). Heavy metals under investigation (Zn, Cu, Mn and Pb) in clear digested solutions were determined using Perkin Elmer Inductively Coupled Spectrophotometer Plasma 400 (ICP). At

Table (1): Some physical and chemical properties of the studied soil.

Parameters	Value	
Particle size distribution		
Coarse sand	54.21	
Fine sand	20.43	
Silt	11.67	
Clay	13.69	
Textural class	Sandy loam	
Soil chemical properties		
OM %	2.63	
pH soil past (extract)	7.83	
EC dS m^{-1}	1.61	
Soluble ions (me q L^{-1})		
Ca^{++}	5.52	
Mg^{++}	3.90	
Na^{+}	4.10	
K^{+}	2.14	
CO_3^{-}	ND	
SO_4^{-}	7.47	
Cl^{-}	4.49	
HCO_3^{-}	3.71	
Plant available heavy metals (mg kg^{-1})		
Elements	Critical limits of heavy metals in soil **	Studied polluted soil
Zn	>1.50	61.31
Cu	>0.50	13.32
Mn	>1.80	23.43
Pb	>0.50	11.30

** Hammissa *et al* .(1993).

Table: (2a) Some chemical properties of the compost

EC dS m^{-1}	pH(1:10)	C/N ratio	OM %	OC%	N%	P%	K%
1.6	6.6	18:1	58.61	25.2	1.4	0.6	0.79

Table: (2b) Some chemical properties of Gypsum

EC dS m^{-1}	pH(1:10)	Ca%	S%	SO_4%
2.3	6.11	16.43	23.56	55.68

the same time, DTPA extractable contents of the studied heavy metals were determined, as mentioned before, at harvest to evaluate the response of their potential mobility and biological uptake by grown plants to the applied chemical amendments. The results of soil and materials analysis before the experiments are presented in Tables 1 and 2.

3.RESULTS AND DISCUSSION

3.1. Impact of different treatments on dry weight of three cuts of Sudan grass

Table (3) and Figs. (1and2) refer to the effect of different treatments on dry weight, content and uptake of Zn, Cu, Mn, and Pb by Sudan grass. Generally, the obtained results showed that the increases in both content and uptake are followed by gradual decrease in the dry weight compared with the control. The data in Table (3) show that the dry weight of shoot was increased in (polluted soil + compost) then decreased gradually until reached (polluted soil + compost + gypsum) and (polluted soil + compost + sulfur + gypsum), respectively. This may be due to the ability role of the added materials particularly those of treatments of polluted soil + compost + gypsum and polluted soil + compost + sulfur + gypsum, to decrease the dry weight production in the polluted soil. The other treatments showed significantly negative influence on dry weight production of the studied plants. The results confirmed the important role (reduce soil reaction pH) of the tested treatment (compost, sulfur and gypsum) on polluted soil. Reduction of dry weight of the plants exposed to Zn, Cu, Mn and pb stress was also recorded in many plants (Revathi *et al.*, 2011).These results agree with the findings of Zancheta, *et al.* (2011), who reported that the EDTA treatment, decreased the pH, thus increased the risk of which could be toxic to plant which could reduce the biomass production. This reduction could be due to their interference with metabolic process associated with normal development (Lidon, and Henriques 1992).

3.2. Impact of different treatments on Zn, Cu, Mn and Pb uptake after three cuts of Sudan grass

Data in Table (3) and Figs. (1 and 2) show a positive effect of different materials in increasing the content and uptake of the studied nutrients by Sudan grass. Concerning the effect of adopted treatments on Zn, Cu, Mn and Pb content and uptake, data in Table (3) showed that Zn, Cu, Mn and Pb contents and uptake are affected by application of materials to polluted soil compared with the other treatments and the control. The dry weight of the plants was reduced with the increases in the concentration and uptake of Zn, Cu, Mn and Pb. The dry weight reflected the high content and uptake of heavy metals found in (polluted soil + compost + sulfur + gypsum) followed by treatment (polluted soil + Compost + gypsum) more than other treatments compared with the control(the three cuts of plants grown on the contaminated soil samples). Also, the values obtained from the other treatments were found to be in between. The total uptake of Zn, Cu and Pb of the three cuts increased gradually (polluted soil + compost), followed by (polluted + compost + sulfur + gypsum) particularly, (polluted soil + compost + gypsum) and (polluted soil + compost + sulfur + gypsum). On the contrary, total Mn uptake was not affected with the different treatments. This remark could be due to Sudan grass which has high ability to accumulate heavy metals specially, Zn, Cu and Pb in harvestable plant tissue. Also, Sudan grass could be considered as a hyper accumulator plant to Zn, Cu, and Pb. Thus, Sudan grass may be used successfully to clean soils contaminated with heavy metals specially Zn, Cu and Pb. These results are in good harmony with Vamerali, *et al.* (2010) who stated that the phytoremediation efficiency of field crops was rarely high, but their greater growth potentialy compared with hyper accumulators should be considered positively, so that they could establish a dense green canopy in polluted soil. These results are also in good agreement with Zancheta *et al.* (2011) who indicated that Cu accumulation in plant tissues was well related to the metal concentration in the nutrient solution, as well as accumulation and transport of Cu to the shoot. Thus, these plant species had potential growth to be employed

Table (3): Impact of different treatments on Zn, Cu, Mn and Pb uptake by three cuts of Sudan grass.

Treatments	Zn									Total uptake (µg pot^{-1})
	Cut No.1			Cut No.2			Cut No.3			
	DW (g pot^{-1})	Con (mg kg-1)	Uptake (µg pot^{-1})	DW (g pot^{-1})	Con (mg kg-1)	Uptake (µg pot^{-1})	DW (g pot^{-1})	Con (mg kg-1)	Uptake (µg pot^{-1})	
1	22.05	0.36	7.93	18.11	0.31	5.68	17.46	0.28	4.88	18.49
2	21.36	1.81	38.66	18.00	1.76	31.68	17.19	1.61	27.67	98.01
3	20.85	1.90	39.61	17.91	1.73	30.98	16.56	1.65	27.32	97.91
4	20.70	1.97	4.77	17.73	1.81	32.09	16.02	1.72	27.55	100.41
5	19.36	2.12	41.02	15.99	2.10	33.57	15.39	1.91	29.39	103.98
6	18.93	3.22	60.95	15.54	3.11	48.32	14.94	2.90	43.32	152.59
7	18.45	3.34	61.62	15.36	3.21	49.30	14.85	2.95	43.80	154.72
LSD at5%	0.19	1.6	1.34	0.143	1.7	1.9	0.14	0.001	1.8	1.8
Cu										
1	22.05	0.22	4.85	18.11	0.20	3.62	17.46	0.20	3.49	11.96
2	21.36	1.86	39.72	18.00	1.70	30.60	17.19	1.61	27.67	97.99
3	20.85	1.81	37.43	17.91	1.72	30.80	16.56	1.69	27.98	96.08
4	20.70	1.91	39.53	17.73	1.81	32.09	16.02	1.72	27.55	99.17
5	19.35	2.41	46.63	15.99	2.13	34.05	15.39	2.00	30.78	113.46
6	18.93	2.55	48.27	15.54	2.20	34.18	14.94	2.12	31.67	114.12
7	18.45	2.70	49.81	15.36	2.29	35.17	14.85	2.15	34.07	119.05
LSD at5%	0.19	1.5	1.73	0.143	1.6	.67	0.14	.016	.035	1.9
Mn										
1	22.05	0.13	2.86	18.11	0.10	1.81	17.46	0.10	1.74	6.45
2	21.36	0.60	12.81	18.00	0.51	9.18	17.19	0.49	8.42	30.41
3	20.85	0.75	15.63	17.91	0.56	10.02	16.56	0.51	8.44	34.09
4	20.70	0.85	17.59	17.73	0.75	13.29	16.02	0.63	10.09	40.97
5	19.35	0.91	17.60	15.99	0.81	12.95	15.39	0.71	10.92	41.47
6	18.93	0.96	18.17	15.54	0.83	12.89	14.94	0.73	10.90	41.96
7	18.45	0.97	17.89	15.36	0.85	13.05	14.85	0.74	10.98	41.92
LSD at5%	0.19	0.001	1.7	0.143	0.005	1.6	0.14	0.018	1.67	1.8
Pb										
1	22.05	0.13	2.86	18.11	0.11	1.99	17.46	0.11	1.92	6.77
2	21.36	1.95	41.65	18.00	1.81	32.58	17.19	1.52	26.12	100.35
3	20.85	2.81	58.58	17.91	2.13	38.14	16.56	1.92	31.79	128.51
4	20.70	2.90	60.03	17.73	2.31	40.95	16.02	2.13	34.12	135.1
5	19.35	3.21	62.11	15.99	2.97	47.49	15.39	2.71	41.70	151.3
6	18.93	3.30	62.46	15.54	3.10	48.17	14.99	2.92	43.62	154.25
7	18.45	3.37	32.17	15.36	3.30	50.68	14.85	2.97	44.10	156.95
LSD at5%	0.19	1.39	1.78	0.143	0.67	0.64	0.14	0.67	0.66	0.012

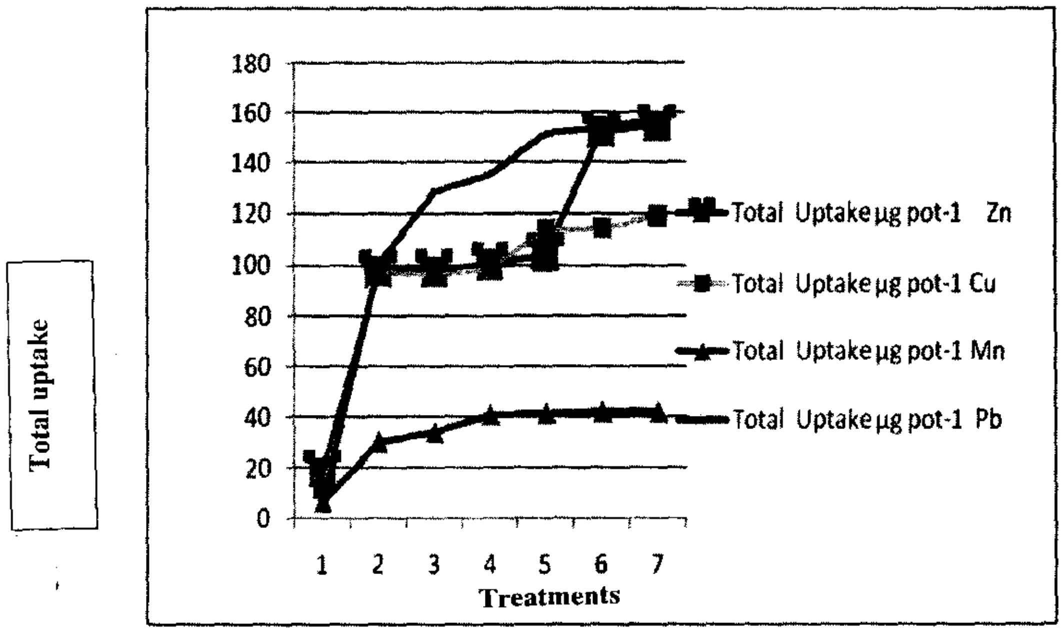
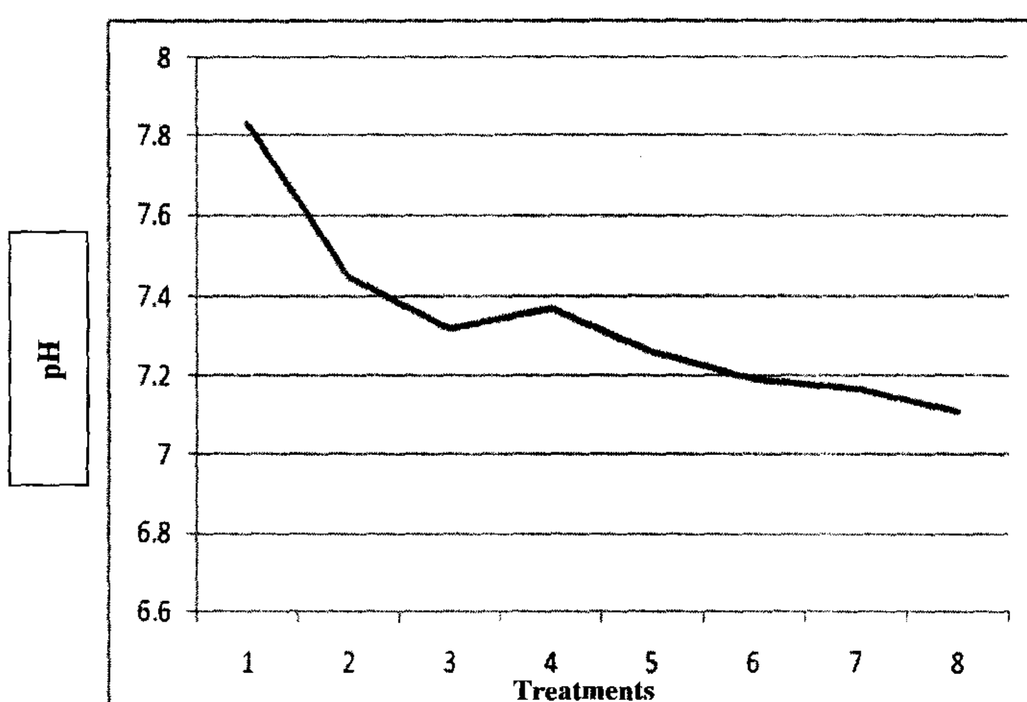


Fig.(1): Impact of different treatments on, Zn,CU,Mn and Pb Uptake in three cuts of Sudan grass.



Treatment 1=pH before seedling and Treatments (2, 3, 4, 5, 6,7and 8) =pH after seedling

Fig.(2): Impact of different treatments on pH values.

in programs of Cu phytoremediation. The results obtained from this study suggest that shoots of Sudan grass facilitated by agronomic practices may be a sustainable technique for partial decontamination of heavy metals from contaminated soils. The application of compost, sulfur and gypsum and consequently the decrease in pH values led to increase the amount of Zn, Cu, Mn and Pb available to the plant. In this regard, Hattori *et al.* (2006) pointed out that lowering pH values led to increasing of Cd uptake in all plant species studied, and concluded that it could be a promising method for phytoremediation of Cd in combination with soil pH adjustments, depending on the tolerance of the plant species to lower pH value.

3.3. Impact of different treatments on availability of Zn, Cu, Mn and Pb to Sudan grass

Data in Table (4) show available Zn, Cu and Pb reduced from the different treatments particularly, treatments No.6 and 7. On the contrary, available Mn was not affected with the different treatments. On the other hand, the data revealed that the highest increase of reduction (%) were 51.12 and 52.12% for Pb, 48.07 and 50.07 for Cu, 43.53 and 45.19 for Zn,14.16 and 16.34 for Mn at No.6 and No.7 treatments, respectively, compared with the other treatments and the control. This reflected the high concentration of heavy metals found in the three cuts of Sudan grass grown on the contaminated soil. The reduction of Zn, Cu, Mn and Pb in the soil after three cuts were found in the following descending order Pb > Cu > Zn > Mn. The phytoremediation of soil could be recommended as an environmentally safe and cheep method for the remediation of heavy metal contaminated soil in Egypt. Revathi, *et al.* (2011) indicated that phytoremediation is found to be cost-effective and highly efficient in remediation heavy metal polluted soils. Also, Souza (2011) indicated that phytoremediation based on the ability of the plants to take up elements from soils with excessive high levels of metals or of other potentially toxic elements and thus contribute to soil decontamination.

3.4. Impact of different treatments on some soil chemical properties after three cuts of Sudan grass

Data in Table (5) show that most of the soil chemical properties after Sudan grass cultivation are nearly the same comparing with those recorded before Sudan grass cultivation. Nevertheless, the most important factor that could be affected by the different treatments is the soil reaction (pH) which was affected by the application of materials like compost, sulfur and Gypsum at all treatments. Data reveal that the lowest value of soil reaction (pH) was recorded for treatments No.7 and No.6 followed by No.5 and No.4 respectively, while the highest value was obtained for control. Also, the values which obtained from the other treatments were found to be in between. This remark emphasized that the soil reaction (pH) played an important role in the chemical behavior of heavy metals in soil. Low pH-values increased the amounts of heavy metals available to plants. Thus, solubility and availability of the micro elements increase as (pH) decrease. Hattori, *et al.* (2006) showed that phytoremediation of heavy metals in combination with soil pH adjustment, depending on the tolerance of the plant species to low pH.

Table (4): Impact of different treatments on available and reduction of Zn, Cu, Mn and Pb in soil after three cuts of Sudan grass.

Treatments	Zn		Cu		Mn		Pb	
	Available (mg kg^{-1})	Reduction %	Available (mg kg^{-1})	Reduction %	Available (mg kg^{-1})	Reduction %	Available (mg kg^{-1})	Reduction %
1	59.93	2.25	13.10	1.65	23.18	1.06	11.22	0.70
2	47.81	22.01	8.12	39.03	21.52	8.15	9.60	15.04
3	42.61	30.50	7.92	40.54	21.48	8.32	9.61	14.95
4	40.11	34.57	7.65	42.56	20.37	13.06	8.11	28.23
5	38.32	37.49	7.10	46.69	20.28	13.44	6.62	41.41
6	34.60	43.53	6.90	48.19	20.11	14.16	5.50	51.32
7	33.60	45.19	6.65	50.07	19.60	16.34	5.41	52.12

Table(5): Impact of different treatments on some soil chemical properties after three cuts of Sudan grass.

Treatments	pH soil past extract	EC dS m^{-1}	Cations meq L^{-1}				Anions meq L^{-1}			
			Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Co_3^{-}	SO_4^{-}	Cl^{-}	HCo_3^{-}
1	7.45	1.52	5.49	3.86	4.10	2.19	0.00	7.44	4.43	3.67
2	7.32	1.49	5.47	3.90	3.98	2.13	0.00	7.41	4.39	3.64
3	7.37	1.49	4.48	3.78	3.97	2.12	0.00	7.40	4.39	3.63
4	7.26	1.48	5.43	3.80	3.96	2.12	0.00	7.41	4.40	3.61
5	7.19	1.47	4.41	3.81	3.95	2.11	0.00	7.40	4.42	3.63
6	7.17	1.46	5.40	3.79	3.92	2.10	0.00	7.38	4.35	3.62
7	7.11	1.45	5.39	3.80	3.91	2.10	0.00	7.39	4.36	3.61

Conclusion

This study was undertaken to evaluate the effect of phytoremediation as a tool for the remediation of some heavy metals polluted soil using Sudan grass. From the obtained results the following could be concluded;

1-Sudan grass has a high ability to accumulate heavy metals specially, Zn, Cu and Pb in harvestable plant tissue. Also, Sudan grass could be considered as a hyper accumulator plant to these metals. Thus, Sudan grass may be used successfully to clean soils polluted with heavy metals specially Zn, Cu and Pb, 2-The important use of compost, sulfur and Gypsum to reduce soil reaction (pH) increased the soluble amount of Zn, Cu, Mn and Pb available to plant, and 3-The phytoremediation of the soil could be recommended as an environmentally safe and cheep method for the remediation of the heavy metal polluted soil in Egypt.

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المعالجة النباتية للتربة الملوثة ببعض الفلزات الثقيلة باستخدام حشيشة السودان

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ملخص

أجريت تجربة اصص في مزرعة كلية الزراعة – جامعة الازهر – مدينة نصر بالقاهرة وذلك لدراسة تأثير المعالجة النباتية باستخدام حشيشة السودان كمحاولة لاستخلاص وازالة بعض الفلزات الثقيلة في تربة ملوثة. جمعت عينات تربة سطحية من مزرعة الجبل الاصفر شمال شرق القاهرة وعوملت بمحسنات (كمبوست – كبريت– جبس) في ستة معاملات بالاضافة الي المعاملة الحاكمة وقد اوضحت النتائج ما يلي :-

١- قدرة وكفاءة نبات حشيشة السودان علي استخلاص وازالة الفلزات الثقيلة من التربة الملوثة قيد التجربة خاصة عناصر الزنك والنحاس والرصاص .

٢- اهمية استخدام محسنات التربة (كمبوست – كبريت – جبس) في خفض الأس الهيدروجيني للتربة مما أدي الي زيادة امتصاص الفلزات الثقيلة داخل أنسجة حشيشة السودان.

٣- يوصي بأستخدام المعالجة النباتية(حشيشة السودان) في الاراضي الملوثة في مصر كأحدي طرق المعالجة الرخيصة الثمن والآمنه بيئيا فى تخليص وازالة عناصر الزنك والمنجنيز والرصاص من التربة الملوثة بتلك الفلزات.

المجلة العلمية لكلية الزراعة – جامعة القاهرة – المجلد (٦٣) العدد الثالث (يوليو٢٠١٢):٣٤٥-٣٥٢.