International Journal of Chemical, Material and Environmental Research 2016, 3 (1): 14-19

Research article

INTERNATIONAL JOURNAL OF CHEMICAL, MATERIAL AND ENVIRONMENTAL RESEARCH
An International Open Free Access, Peer Reviewed Research Journal

ISSN 2410-5945
2016, Vol. 3, No. 1:
pg. 14-19

Effect of Citric Acid on Cadmium Ion Uptake and Morphological Parameters of Hydroponically Grown Jute Mallow (*Corchorus olitorius*)

M. S. Hassan[1, *], M. S. Dagari [2], A. A. Muazu[1], K. A. Sanusi[1]

[1]Department of Chemical Sciences, Federal University Kashere, Gombe State, Nigeria
[2]Department of Pure and Industrial Chemistry, Federal University Gashua, Yobe State, Nigeria

(Received: April 01, 2016; Accepted: May 3, 2016)

Abstract

This research work investigates the possibility of improving the phytoextraction of cadmium (Cd) by the application of citric acid (CA). For this purpose, plants were grown in hydroponics under controlled conditions. Addition of 1, 5, 10 and 20 mg/L Cd^{2+} significantly decreased the plant growth and biomass. The effects were dose dependent with obvious effects at higher Cd^{2+} concentration of 20 mg/L. Application of CA significantly depressed Cd^{2+} uptake and its accumulation in plant roots and shoots. CA alleviated Cd^{2+} toxicity by increasing plant biomass, photosynthetic and growth parameters. The results showed that heavy metal accumulated more in roots than the shoots and application of CA depressed Cd^{2+} uptake at all concentrations. Jute mallow *(Corchorus olitorius)* proved to be an effective accumulator for Cd, however, neither concentration of CA showed advantages for phytoextraction of Cd. The results showed that jute mallow is a potential plant for phytoextraction of Cd without the use of CA as enhancer.

Keywords: Cadmium, citric acid, phytoextraction, biomass, jute mallow, *Corchorus olitorius*

1. Introduction

Among the heavy metals, cadmium (Cd) is a highly toxic, non-essential and carcinogenic element [1]. In plants, Cd^{2+} enters mainly through root uptake and is transported to above ground parts [2]. Higher Cd^{2+} concentration in plants caused several physiological and biochemical disorders including reduced growth and yield, nutrient uptake, changes in chloroplast ultrastructure and initiation of oxidative stress [3, 4]. Food chain Cd contamination is the main source of Cd entry to human and the main constraint for food safety and agricultural land quality [5].Therefore, different actions can be undertaken to remediate Cd contaminated soils including in situ remediation techniques. Plant based remediation techniques are becoming more wide spread as these are environmental friendly and cost effective [6]. A previous study was conducted using citric acid (CA) for Cd uptake by *Brassica napus L.* in a hydroponic experiment [6]. Phytoremediation is a biological technique, considered for clean-up of polluted sites because of its economical, visual advantages and extensive applicability [3]. Phytoextraction is a technique which uses plants to hyperaccumulate metals in to harvestable plants. The degree of metal, translocation from root to aerial plant parts depends upon plant species, metal and environmental conditions [7]. Jute mallow is tolerant to metal stress, has high biomass, the second most important source of fiber after cotton and the ability of jute mallow to give some financial benefit after harvesting makes it a potential plant for phytoremediation [8].

* Corresponding author:
sanninmc@yahoo.com
Published online at www.ijcmer.org

Phytoremediation studies by jute mallow carried out on oil contaminated soils, in which parameters, such as plant height, fresh and dry weight were measured showed that spent oil has inhibitory effects on the growth and yield of jute mallow [9]. Moreover, the assessment of heavy metals bioaccumulation by vegetables including jute mallow in kaduna metropolis, Nigeria showed that the mean concentration of the metals are generally higher than the WHO/FAO permissive limits. This calls for concern especially in the case of Pb and Cd which are highly toxic and are not known for any biological use [10].

The objectives of the research are; to study the bioaccumulation capability of jute mallow, to use jute mallow as hyperaccumulator and the possibility of using jute mallow for phytoremediation.

2. Materials and Methods

2.1. Growth Conditions and Treatments

Eight week old seedlings of jute mallow *(Corchorus olitorius)* were collected from the Department of Agronomy farm, Bayero University, Kano on Thursday 20th November, 2014 by 9.00am. After washing with tap water to remove the soil, they were rinsed with deionised water and replanted in hydroponic solution. They were carefully monitored in a greenhouse for ten days under the conditions: 65% relative humidity, 14 hr per day, 10 hr per night under a light intensity of 600 μ mol m^{-2} s^{-1}, and average temperatures 39/24°C. Hoagland nutrient solution was used in the experiment which was made of 5 mM KNO_3; 5 mM $Ca(NO_3)_2$; 1 mM KH_2PO_4; 2 mM $MgSO_4$; 46.3 μM H_3BO_3; 11.8 μM $MnCl_2$. $4H_2O$; 0.7 μM $ZnSO_4$.$7H_2O$; 0.32 μM $CuSO_4.5H_2O$; 0.16 μM $H_2MoO_4.H_2O$, and 12.5 μM Fe-EDTA. The treatments consisted of five Cd dosages (0, 1, 5, 10, and 20 mg/L) supplied as $Cd(NO_3)_2.4H_2O$. In the second phase, 5 mM of CA were added while varying the concentrations of Cd^{2+} from 0, 1, 5, 10, and 20 mg/L. Each treatment was triplicated and allowed to stand for ten days [11]. The plants were harvested from the hydroponic solution and washed with tap water, rinsed with 1% HNO_3 followed by deionised water and then wiped with tissue paper. They were then dried in an oven at 65°C. The weight of each plant harvested was recorded. The plants were then sorted into roots and shoots.

2.2. Heavy Metal Content and Statistical Analysis

The roots and shoots of the plants harvested were ground to fine powder. Based on availability, 0.5 g (root) and 1.0 g (shoot) were used for the various analyses. They were weighed into porcelain crucibles and ashed at 450°C in a muffle furnace to constant weight. The ash was dissolved in 0.1 $moldm^{-3}$ nitric acid, filtered and made to mark in a 50 mL volumetric flask. The plants extracts and blank were stored at low temperature before analysis [12]. The concentration of Cd in plant root and shoot were determined by using atomic absorption spectrometer (model PG990). Analysis of variance (ANOVA) using the SPSS software was performed to check the accuracy and validity of the results. Data were expressed as mean followed by SD. Statistical significance was assumed at $P<0.05$.

2.3. Determination of Morphological Parameters

The changes in length and weight of the root and shoots were determined as follows: ***Change in Root length (ΔRtL)*** = Root length for a given treatment – Root length of control, ***Change in Shoot length (ΔShL)*** = Shoot length for a given treatment – Shoot length of control, ***ΔDWP*** = Change in dry weight of plant = Dry weight of plant in a particular treatment – Dry weight of plant in control. If ***ΔDWP*** was positive, the dry weight was bigger in a plant grown in a particular treatment compared to the control. A negative value showed the reversed effect.

3. Results and Discussions

3.1. Cadmium Concentration and Uptake by Jute mallow

Cd concentrations in roots and shoots (leaf and stem) of jute mallow plants were significantly increased ($p<0.05$), when plants were exposed to Cd at varied concentrations (1, 5, 10 and 20 mg/L) relative to the control plants (Figure 1). Cd concentration in roots and shoots gradually increased with increasing Cd^{2+} concentration in the hydroponic treatment. The root accumulated the largest Cd^{2+} per concentration in all treatment. Interestingly, application of CA at constant concentration (5mM) significantly decreased ($p<0.05$) Cd concentrations in roots and shoots as compared to treatment without CA (Figure 1).

The changes in translocation factor (TF) and bioconcentration factor (BCF) against the concentrations of added Cd^{2+} are shown in Figures 2 and 3. According to Chen *et al.* [13], TF is the ratio of the concentration of a metal in the aerial part of a plant to its concentration in the root. In this study, the ratio can be used to evaluate the translocation effects of jute mallow seedlings replanted in hydroponic solutions. TF varied significantly with concentration of added Cd^{2+} ($P < 0.05$). Thus, a relatively good fraction of the Cd^{2+} was translocated to the shoots (Figure 2). The BCF is the ratio of the metal concentration in the root to its concentration in the solution. The value was used in this research to explain the uptake of Cd^{2+} ion by jute mallow from the solution to its root. The BCF showed that the bulk concentration of Cd^{2+} was absorbed by the roots (Figure 3).

3.2. Effects of Cadmium ion and Citric Acid on Morphological Parameters of Jute Mallow

The changes in lengths and weight of roots and shoots of the seedlings significantly decreased ($P < 0.05$) with Cd^{2+} application compared to the control plants (Figures 4a and 4b). Furthermore, the reduction was more obvious at higher Cd^{2+} treatment (20 mg/L). Addition of CA (5mM) in the culture medium significantly increased ($P<0.05$) these plant parameters as compared to respective Cd^{2+} treatments without CA addition.

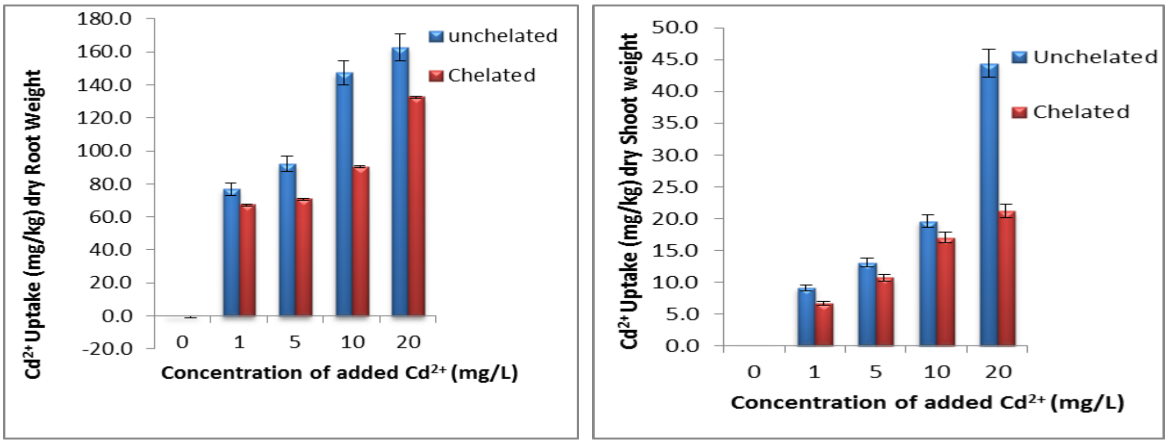

Figure 1. Cd^{2+} Uptake by Unchelated and Chelated Hydroponically Grown Jute Mallow *(Corchorus olitorious*)

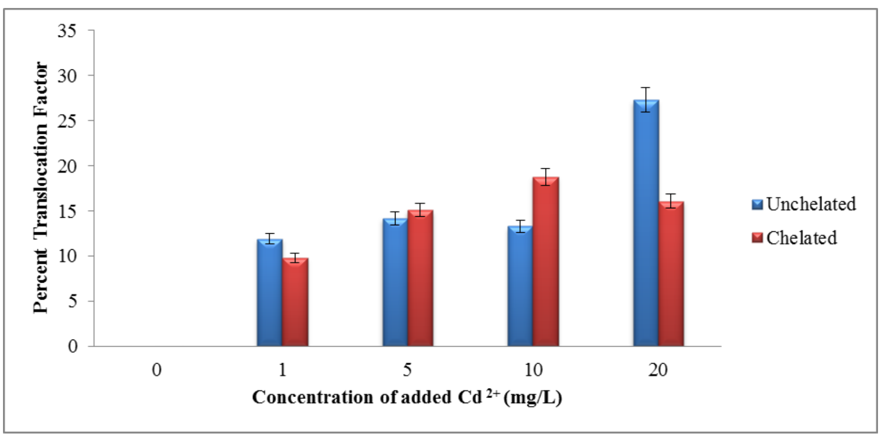

Figure 2. Translocation Factor of Cd^{2+} in Jute Mallow Grown in Unchelated and Chelated (5mM) Treatment.

The addition of CA improved growth characteristics by reducing the inhibitory effects of Cd^{2+} at both levels of stress showing that CA obviously ameliorated Cd^{2+} toxicity symptoms in jute mallow. The response of plant biomass parameter such as shoot and root dry weight, is shown in Figures 5a and 5b. Application of Cd^{2+} reduced shoot and root dry weights as compared to control plants. Plant biomass parameters gradually decreased with increasing Cd^{2+} treatments. The addition of CA significantly increased ($P<0.05$) dry weights, shoots and roots under both 10 and 20 mg/L Cd^{2+} treatments as compared to respective treatments without CA application.

Several researchers have documented that CA addition increased plant growth and biomass under metal stress in *Juncus effuses* [14]. The success of phytoextraction is evaluated by the quantity of biomass, the absorption of metals in plant materials, and bioavailable percentage of heavy metals in the rooting portions (McGrath, 1998). Increase in plant biomass may be due to enhanced nutrient uptake by plants [14], efficient sulphate uptake and assimilation[3], synthesis of phytochelatins (PCs) in plants [15] or the ability of plant species to detoxify Cd^{2+} [16].

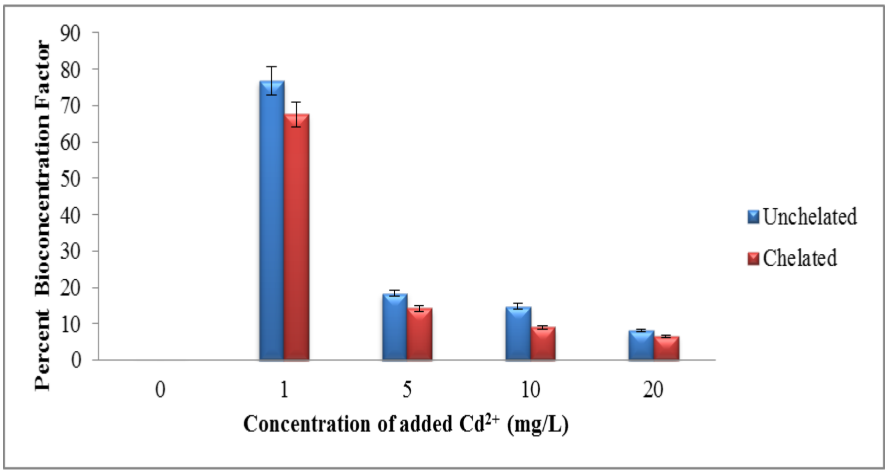

Figure 3. Bioconcentration Factor of Cd^{2+} in Jute Mallow Grown in Unchelated and Chelated (5mM) Treatment.

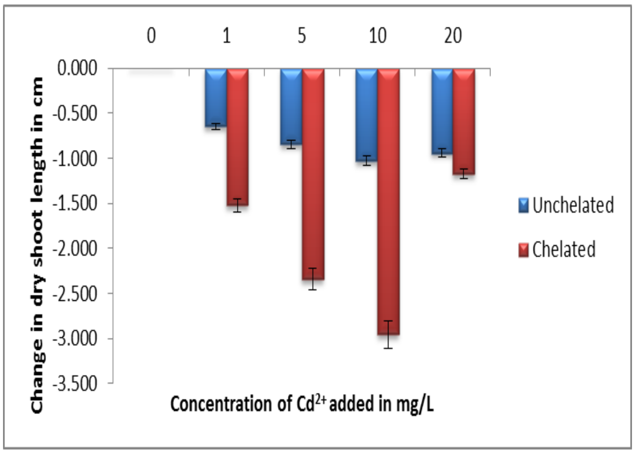

Figure 4a. Changes in Dry Shoot Lengths of Jute Mallow

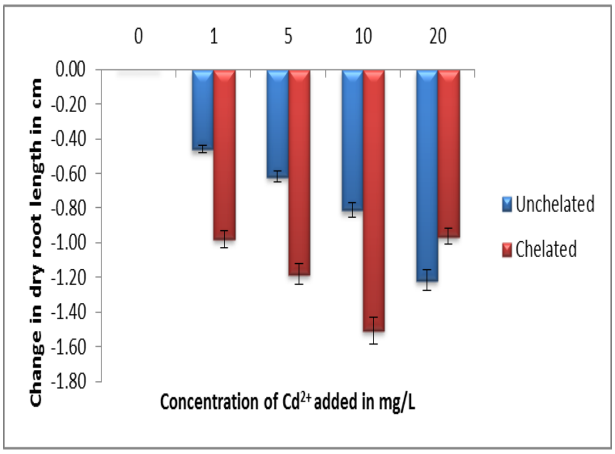

Figure 4b. Changes in Dry Root Length of Jute Mallow

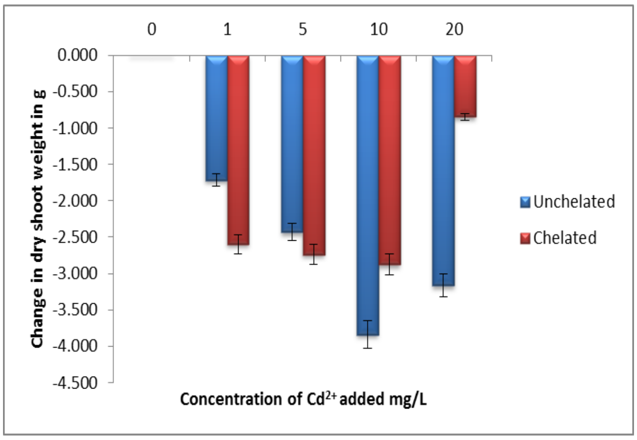

Figure 5a. Changes in Dry Shoot Weights of Jute Mallow

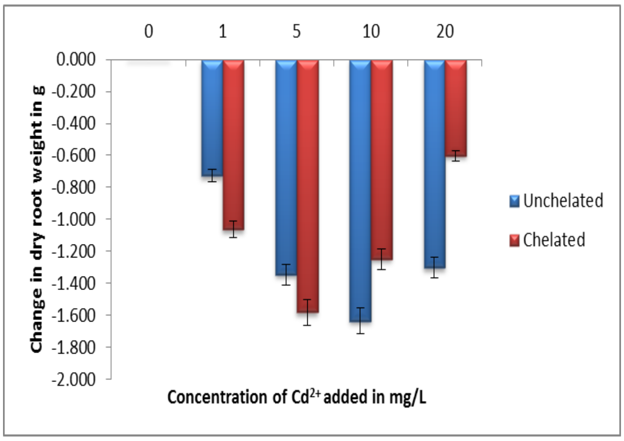

Figure 5b. Changes in Dry Root Weights of Jute Mallow

There was increase in Cd^{2+} concentration and uptake by jute mallow in roots and shoot with increasing Cd^{2+} levels in the nutrient solution (Figure 1). These results are in consonance with the previous findings in some plants like *B. napus L.* [16, 17, 18]. Application of CA at 5mM increased Cd^{2+} concentration and uptake by the plants as compared to the control, but decreased Cd^{2+} concentration and uptake by the plants as compared to the Cd treated plants (Figure 1). Reduced uptake in Cd^{2+} treated plants might be due to the transformation Cd^{2+} to relatively stable organic and residual forms by CA [19]. The distribution of metals with plant tissues is an important property that can act as an indirect indicator of detoxification mechanism. In the present study, Cd^{2+} accumulation was less than 500 mg/kg with the highest Cd^{2+} concentration in the nutrient solution. Cd concentration in shoots of *B. napus L.* has been reported up to 555 mg/kg dry weight only on exposure for fifteen days [17] and about 240 mg/kg dry weight only on exposure for ten days in solution [20].

Cd concentration in plants varies with type, genotype and duration of Cd^{2+} exposure to plants as of *B.napus L*. [16] and *B. juncea* [4]. It has been reported that plant may have no limitation of Cd^{2+} uptake until Cd^{2+} caused significant damage to plants [18, 21]. Upper threshold of Cd^{2+} accumulation in jute mallow has not been shown and further study is required in order to investigate the limitation of Cd^{2+} accumulation in plants. In the present study, duration of plant exposure to Cd^{2+} was short, ten days and CA application enhanced antioxidant enzyme activity and gas exchange parameters which may increase Cd^{2+} in the shoots and roots. Moreover, jute mallow may accumulate relatively high Cd^{2+} in shoots and roots after a long term exposure, judging from the growth characteristics being exhibited by the plants. However, further research is required to evaluate, the jute mallow ability to uptake Cd^{2+} from the hydroponic solution especially with CA application and its utilization as an hyperaccumulator.

4. Conclusion

The results indicated that Cd^{2+} supply significantly depressed plant growth and biomass. Addition of CA alleviated Cd^{2+} toxicity by its uptake and accumulation, through CA chelating property and increased antioxidant capacity when compared with Cd^{2+} treatment alone. Thus, the results showed that heavy metal accumulated more in roots than the shoots and application of CA depressed Cd^{2+} uptake at all concentrations. Jute mallow proved to be an effective accumulator for Cd, however, neither concentration of CA showed advantages for phytoextraction of Cd. The results can be beneficial to the society in the monitoring of areas contaminated by heavy metals as a result of mining and industrial activities.

ACKNOWLEDGEMENTS

My acknowledgement goes to the Head of Department Plant Biology, Mr. Joseph of the Department of Pure and Industrial Chemistry, and Sama'ila Ibrahim of Agronomy Department, Bayero University, Kano. They all made invaluable contribution to the success of this research.

REFERENCES

[1] Alloway B.J., Jackson A.P., 1991. The behaviour of heavy metals in sewage sludge-amended soils. Science of the Total Environment, 100, 151-176

[2] Liu D.H., Wang M., Zou J.H., Jiang W.S., 2006. Uptake and accumulation of cadmium and some nutrient ions by roots and shoots of maize (*Zea mays* L.). Pak. J. Bot., 38, 701-709.

[3] Sun Q., Ye, Z.H., Wang, X.R., Wong, M.H., 2007. Cadmium hyperaccumulation leads to an increase of glutathione rather than phytochelatins in the cadmium hyperaccumulator *Sedum alfredii*. J. Plant Physiol., 164, 1489-1498.

[4] Gill S.S., Khan N.A., Tuteja N., 2011. Differential cadmium stress tolerance in five Indian mustard (*Brassica juncea L.)* cultivars an evaluation of the role of antioxidant machinery. Plant Signal. Behav., 6, 293-300.

[5] Atafar Z., Mesdaghinia A.R., Nouri J., Homaee M.,Yunesian M., Ahmadimoghaddam M., Mahvi A.H., 2010. Effect of fertilizer application on soil heavy metal concentration. Environ. Monitor. Assess, 160, 83–89.

[6] Sana E., Shafaqat A., Shamaila N., Khalid M., Mujahid F., Wajid I., Muhammad B.S., Muhammad R., 2014. Citric acid assisted phytoremediation of cadmium. Ecotox. & Env. Safety, 106, 164-172.

[7] Jadia C.D., Fulekar M.H., 2008. Phytotoxicity and remediation of heavy metals by fibrous root grass in soil -vermicompost media. J. Appl. Biosci., 10, 491-499.

[8] Robinson B.H., Millis T.M., Petit D., Fung L.E., Green S.R., Clothier B.E., 2000. Natural and induced cadmium accumulation in poplar and willow; implications for phytoremediation. Plant Soil, 227, 301-306.

[9] Nkereuwem M.E., Edem I.D., Fagbola O., 2010. Bioremediation of oil-polluted soils with oganomineral fertilizer (OMF) and Mexican sunflower (Tithonia diversifolia). Nig. J. of Agric., Food & Environ. 6(182), 13-20.

[10] John O.J., Samuel E.K., 2012. Assessment of heavy metal bioaccumulation in spinach, jute mallow and tomatoes in farms within kaduna metropolis, Nigeria. Amer. J. of chem. (2)1, 13-16

[11] Chan K.F., Yeh T.Y., Lin C.F., 2011. Phytoextraction of Cu, Zn and Pb Enhanced by Chelators with Vertiver (*Vetiveria Zizanioides*); Hydroponic and Pot Experiments. ISRN Ecology, 2012, 1-12.

[12] IITA (International Institute of Tropical Agriculture) 1979. Laboratory manual on basic soil and plant analyses, 3rd edn., Longman London, UK, pp 9-67.

[13] Chen Y.X., Lin Q., Luo Y.M., He Y.F., Zhen S.J., Yu Y.L., Tian G.M., Wong M.H., 2003. The role of citric acid on the phytoremediation of heavy metal contaminated soil. Chemosphere, 50(6), 807-811.

[14] Najeeb U., Jilani G., Ali S., Sarwar M., Xu L., Zhou W., 2011. Insights into cadmium induced physiological and ultra-structural disorders in *Juncus effusus L.* and its remediation through exogenous citric acid. J. Hazard. Mater., 186, 565-574.

[15] Muhammad D., Chen F., Zhao J., Zhang G., Wu F., 2009. Comparison of EDTA-and citric acid-enhanced phytoextraction of heavy metals in artificially metal contaminated soil by *Typha angus tifolia.* Int. J. Phytoremediation, 11, 558-574.

[16] Ghani A., 2011. Varietal differences in canola (*Brassica napus L.*) for the growth yield and yield components exposed to cadmium stress. J. Anim. Plant Sci., 21, 57-59.

[17] Haouari C.C., Nasraoui A.H., Bouthour D., Houda, M.D., Daieb C.B., Mnai J., Gouia H., 2012. Response of tomato (*Solanum lycopersicon*) to cadmium toxicity: growth, element uptake, chlorophyll content and photosynthesis rate. Afr.J. Plant Sci. 6, 1-7.

[18] Park J., Kim J.Y., Kim K.W., 2012. Phytoremediation of soil contaminated with heavy metals using *Brassica napus.* Geosyst. Eng., 15, 10-18.

[19] Mojiri A., 2011. The potential of corn *(Zea mays)* for phytoremediation of soil contaminated with cadmium and lead. J. Biol. Environ. Sci., 5(13), 17-22.

[20] Meng H., Hua S., Shamsi I. H., Jilani G., Li Y., Jiang L., 2009. Cd-induced stress on the seed germination and seedling growth of *Brassica napus L*. and its alleviation through exogenous plant growth regulators. Plant Growth Regul., 58, 47-59.

[21] Chakroun H.K., Souissi F., Bouchardon J.L, Souissi R., Moutte J., Faure O., Remon E., Abdeljaoued S., 2010.Transfer and accumulation of lead, zinc, cadmium and copper in plants growing in abandoned mining-district area. Afr. J. Environ. Sci. Tech., 4(10), 651-659.