Chelate Assisted Chromium Uptake by Indian Mustard in Tannery Sludge Contaminated Soil

Weimin You*[*], *Tianduo Li

School of Light Chemistry and Environmental Engineering, Shandong Institute of Light Industry, Jinan, 250353, Shandong, P.R. China

Abstract: Pot experiments were conducted to investigate the effect of different chelating agents (oxalic acid, malic acid, citric acid and EDTA) on Cr uptake by Indian mustard in tannery sludge contaminated soil. The results indicate that Cr uptake in shoot of Indian mustard significantly increased with the application of EDTA and citric acid to soil, but reduced in the root. The percentage of total Cr of shoot in the plant increased to 85% and 90% with the addition of citric acid and EDTA respectively. In a word, the treatments with citric acid and EDTA are suitable to the phytoextraction of Cr-contaminated soil.

Key words: chelating agents; Indian mustard; uptake; soil; chromium

1 Introduction

The use of plants to remove toxic metals from soil (phytoremediation) is emerging as a potential strategy for cost-effective and environmentally sound remediation of contaminated soils. [1]

The success of phytoremediation is dependant on several factors. Plants must produce sufficient biomass while accumulating high concentrations of mental. The metal-accumulating plants also need to be responsive to agricultural practices to allow repeated planting and harvesting of the metal-rich tissues. In addition, these plants preferentially accumulate environmentally important toxic metals. Known metal accumulators do not meet these criteria[2-5]. The ability to cultivate a high biomass plant with a high content of toxic metals on a contaminated soil will be a determining factor in the success of phytoremediation. Therefore, enhancing metal accumulation in existing high yielding crop plants without diminishing their yield is the most feasible strategy in the development of phytoremediation. [6]

Cultivars *Brassica juncea* (Indian mustard, a high biomass forage and oil crop) have also demonstrated the ability to accumulate multiple toxic metals in shoot tissues when grown in nutrient solution with high concentrations of soluble metals. [7]

In this paper, we report on the enhanced uptake of chromium accumulation in tannery sludge contaminated soil by Indian mustard with chelating agents. The magnitude of this enhancement may be sufficient to make phytoextraction of Cr-contaminated soils a viable environmental technology.

2 Experimental

2.1 Materials

The selected properties of the experimental soil are presented in Tab. 1. The soil was screened to pass though a 1.0cm sieve. The soil was then air-dried to approximately 8% water content and mixed with tannery sludge. The physical and chemical properties are presented in Tab. 2. The concentration of chromium in the mixed soil was 208mg/kg. The experimental plant was *Brassica juncea* (Indian mustard).

[*] Corresponding author. Phone: +86-0-13969116806. E-mail: youweimin@126.com.

Tab. 1 Characteristics of soil used in this study

Soil properties	Content
Organic mater content (%)	1.5
Soil pH(1:5 soil/water ratio)	6.5
Total soil Cr($mg.kg^{-1}$)	13
Total N($g.kg^{-1}$)	0.62
P_2O_5($g.kg^{-1}$)	0.51

Tab. 2 Characteristics of tannery sludge

Properties	Content
Water (%)	75.4
Total solid (%)	25.6
Volatile solid (%)	69.7
C(dry weight, $g.kg^{-1}$)	189.0
N(dry weight, $g.kg^{-1}$)	48.8
Cr(dry weight, $g.kg^{-1}$)	28.5
NH_4^+-N(fresh weight, $g.kg^{-1}$)	1.4
pH	8.05

2.2 Experimental design and analysis methods

The amended soil was allowed to equilibrate for a period of two weeks in the greenhouse undergoing three cycles of saturation with water and air drying before remixed and planted. The soil was placed in pots (500g of soil/pot) and planted with *Brassica juncea* seeds. After seeding emergence, the pots were thinned to 4 plants per pot. The soil was irrigated to field capacity on a daily basis. Before the harvest 2 weeks, the chelating agents (4mmol/kg) were added in the soil. The plants were harvested after growing for 6 weeks by cutting the stem 1cm above the soil surface. Root and shoot tissue was collected and washed with DI water to remove soil deposition before analysis. The plant tissue was dried at 70℃ and wet-ashed using HCl-HNO_3-$HClO_4$[8]. The resulting solution was analyzed for metal content by ICP-AES.

Soil samples were collected from the pots and analyzed for water-soluble metals by equilibrating 2.5g of soil with 25ml of 0.01M KNO_3 for 2 hours[9]. The suspensions were centrifuged and the supernatant solution was analyzed for soluble chromium by ICP-AES.

3 Results and discussions

3.1 Activation of chromium in tannery sludge contaminated soil by chelating agents

The soluble mental concentration in the soil is expected to play a large role in determining the metal uptake by the plant and the metal content of the shoot material[10]. Through the addition of EDTA, malic acid and citric acid to Cr-contaminated soil, the soluble Cr contents in soil were enhanced. In the case of oxalic acid, however, the addition of oxalic acid to the Cr-contaminated soil did not significantly enhance the soluble Cr content in soil compared to the control. The application of EDTA, malic acid and citric acid to the soil solubilized Cr in soil. The EDTA application produced the highest soluble Cr in soil, and the concentration of soluble Cr was about 4 times compared to the control (Fig. 1).

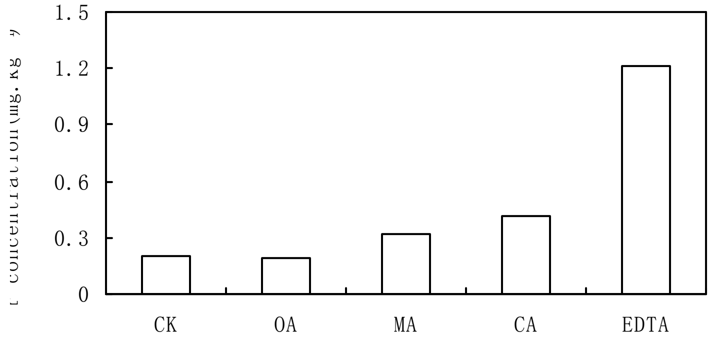

Fig. 1 Effect of chelating agents on soluble Cr concentration in soil

3.2 Effect of different chelating agents on biomass of Indian mustard

Plant dry matter yield was not significantly affected by the application of OA, MA and CA. The shoot and root dry weights were significantly reduced by the application of EDTA to 3.12g.pot^{-1} and 0.58g.pot^{-1} compared to 4.01 g.pot^{-1} and 0.91 g.pot^{-1}t in the control (Fig.2 and Fig.3), but the Indian mustard did not appear poisoning symptoms.

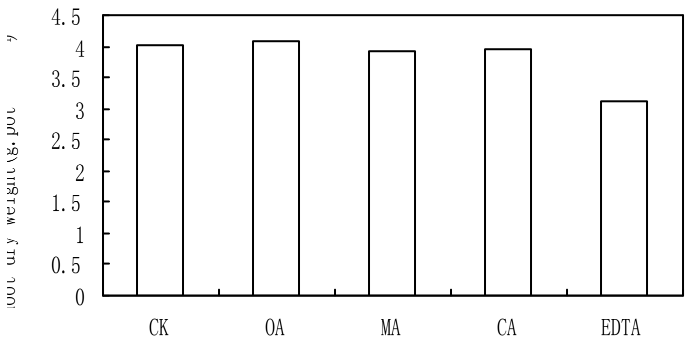

Fig. 2 Effect of chelating agents on shoot dry weight of Indian mustard

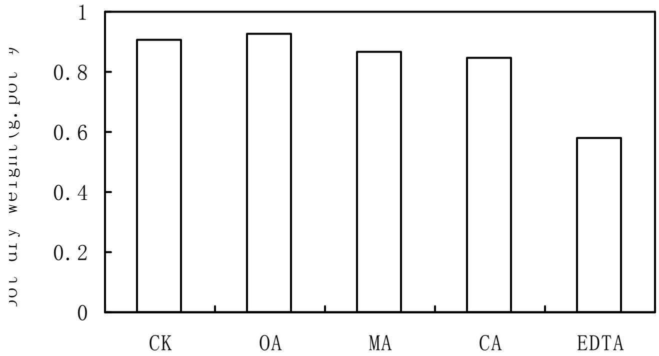

Fig. 3 Effect of chelating agents on root dry weight of Indian mustard

3.3 Effect of different chelating agents on shoot and root chromium concentration of Indian mustard

The shoot uptake of Cr was enhanced through the addition of chelating agents to the soil (Fig. 4). The addition of EDTA to the soil increased the Cr concentration of shoot to 160.7mg/kg as compared to only 37.1 mg/kg in the control. Citric acid and malic acid were less effective than EDTA but still produced Cr accumulations of approximately 120.2mg/kg and 50.3mg/kg. Oxalic acid amendments did not significantly increase Cr uptake compared to the control treatment.

The root uptake of Cr was reduced through the addition of chelating agents to the soil. The addition of oxalic acid, malic acid, citric acid and EDTA to the soil reduced the Cr concentration of root to 118.5mg/kg, 120.3mg/kg, 100.6mg/kg and 85.3mg/kg as compared to 159.2mg/kg in the control.

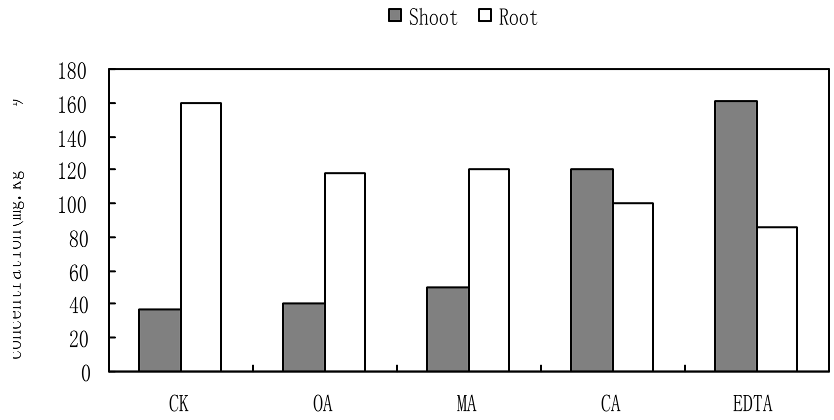

Fig. 4 Shoot and root chromium concentration of Indian mustard

3.4 Distribution of chromium in Indian mustard by different chelating agents' treatments

The addition of oxalic acid, malic acid, citric acid and EDTA to the soil enhanced the percentage of total Cr of shoot in the plant. The addition of citric acid and EDTA increased the percentage to 85% and 90% as compared to only 51% in the control (Tab. 3). For this reason, the treatments by citric acid and EDTA suit to the phytoextraction of Cr-contaminated soil.

Tab. 3 Distribution of Cr in Indian mustard by different chelating agents' treatments

Cr concentration in soil($mg.kg^{-1}$)	Total Cr of shoot ($ug.pot^{-1}$)	Percentage of total Cr of shoot in the plant (%)	Total Cr of root ($ug.pot^{-1}$)	Percentage of total Cr of root in the plant (%)
CK	148.77	51	144.87	49
OA	166.1	60	110.21	40
MA	196.67	65	104.66	35
CA	474.79	85	85.51	15
EDTA	501.38	91	49.47	9

3.5 Effect of different chelating agents on transfer coefficients

Transfer coefficient (the ratio of Cr concentration in shoot to root) indicated the metal's transferring capability in plant. The addition of citric acid and EDTA increased the transfer coefficient to 1.19 and 1.88 as compared to only 0.23 in the control. Oxalic acid and malic acid were less effective than citric acid and EDTA but still produced the transfer coefficient approximately 0.34 and 0.42(Fig. 5).

Fig. 5 Transfer coefficient at different treatments

4 Conclusions

EDTA and citric acid can significantly enhance the soluble Cr concentration in tannery sludge contaminated soil. The dry weight of Indian mustard was significantly reduced by the application of EDTA, but the Indian mustard did not appear poisoning symptoms. However, the dry weight of plant was not significantly affected by the application of oxalic acid, malic acid and citric acid. The addition of citric acid and EDTA to the soil significantly increased the Cr concentration of shoot， but reduced the Cr concentration of root. The addition of citric acid and EDTA increased the percentage of total Cr of shoot in the plant to 85% and 90%, and the transfer coefficients were greater than 1, so the treatments by citric acid and EDTA suit to the phytoextraction of Cr-contaminated soil.

References

[1] M. J. Blaylock; D. E. Salt; S. Dushenkov; et al. Environ. Sci. Technol. 1997, 31, 860-865.

[2] C. R. Zheng; H. M. Chen. Heavy Metal Pollution in Soil-plant System. Beijing: Geological Publishing House.1996: 210-250.

[3] S. D. Ebbs; L. V. Kochian. Environ. Sci. Technol.1998, 32 (6):802-806.

[4] A. J. M. Baker; R. D. Reeves; A. S. M. Hajar. New Phytol.1994, 127: 61-68.

[5] P. B. A. N. Kummar; V. Dushenkov; H. Motto; et al. Environ. Sci. Technol. 1995, 29:1232-1238.

[6] J. W. Huang; J. Chen; W. R. Berti; et al. Environ. Sci. Technol.1997, 31: 800-805.

[7] J. Wu; F. C..Hsu; S. D. Cuningham. Environ. Sci. Technol.1999, 33: 1898-1904.

[8] J. Escarre; C. Lefebvre; W. Gruber; et al. New-Phytologist, 2000, 145: 429-437

[9] A.J.M. Baker; S. P. Mc Grath; C.M.D. Sidoli; et al. Rea Conserv Rec.1994b, 11: 41-49.

[10] M. M. Lasat. Journal of environmental quality, 2002, 31:109-120.