An Investigation on Migration of Uranium in Soils and Plants in a Phytoremediation System

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Introduction

Plant species have shown the capability to absorb U into the biomass. Norman(1952) even suggested that uranyl ion acts as an accessory microelement in growth of Lemna and flax roots. The plants, termed metal hyperaccumulators, can extract and accumulate more than 1000-10,000mg heavy metal per kilogram of dry weight of plants (0.1-1%). The most vital main factors influencing the ability and efficiency of phytoremediation is the ability of the plant to uptake the metals from soil before the accumulation mechanism happens in the plant tissue. Huang(1998) reported *Brassica juncea* had a capacity to accumulate 5,000mgKg^{-1} U in the shoots by the enhancement of citric acid. Dushenkov(1997) reported that the bioaccumulation coefficients of *Helianthus annuuus* based on the ratios of U concentration in the roots vs. U concentration reached 30,000 in the aqueous phase system. The low solubility of heavy metals and radioactive nuclides in the soil is usually a limiting factor in metal extraction by plants. Adding chelating compounds that solubilize non-available heavy metal should increase metal uptake by plants. For example, Huang(1998) showed citric acid could trigger uranium hyperaccumulation in some plant species, including *Brassica juncea*, by more than 1000 fold within a few days. It has been shown that phytoremediation using conventional plants has some potential for use in remediation; but also that it is encumbered by limitations that prevent widespread benefits from its significant economies.

Materials and Method

Soil

Soils were soaked in uranium nitrate solution for one week, and the soils were washed two times to remove the residual spike solution. Soil pH was measured using 1:1 soil/eater ratio; soil uranium was determined by the EPA-3050 method. Two types of soils with different texture were prepared to test the effect of soil type. The selected properties of the U-contaminated soils are shown in Table 1.

Table 1. Properties of the U-contaminated soils

Soil properties	Clayey	Sandy
Sand(%)	25	40
Silt%	35	40
Clay%	40	20
pH	6.0	6.5
Total U(mg/Kg)	450	450

Plant

For each experiment, 500g of the U-contaminated soil was placed in a pot (15cm high, 8cm diameter) Seeds of selected plant species were sown in the soil, and the seedling were grown in the greenhouse at 30℃. Plant species tested were the followings: *Brassica chinensis* var. *oleifera, Brassica juncea* L., *Brassica napus* L., *and Helianthus annuus* L. After growing in uranium-spiked soils with two levels of clay for six weeks, plants were treated with citric acid solution (pH=1.8) every other day for ten days totally. Plants were harvested 1 week after the application of citric acid. Plant tissues were collected separately according to the physiological structure. Above ground samples were wash with deionized water, and the roots were washed with 0.1% $HClO_4$ acid and rinsed with deionized water for three times.

Key words: Phytoextraction, uranium, citric acid, soil remediation

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Sample analysis

The plant samples were digested with nitric acid and hydrogen peroxide. The digested samples were brought to a constant volume with deionized water, and the digests were analyzed for U by Inductively Coupled Plasma - Mass Spectrometry (ICP-MS).

Results and Discussion

(1) Uranium distribution in different portions of plant

Except *B. juncea*, plants contained more uranium in roots more then aboveground tissues. Flowers and seeds of *H. annuus* contained almost no U. *B. juncea* is the only species that contained higher U in roots than in aboveground tissues.

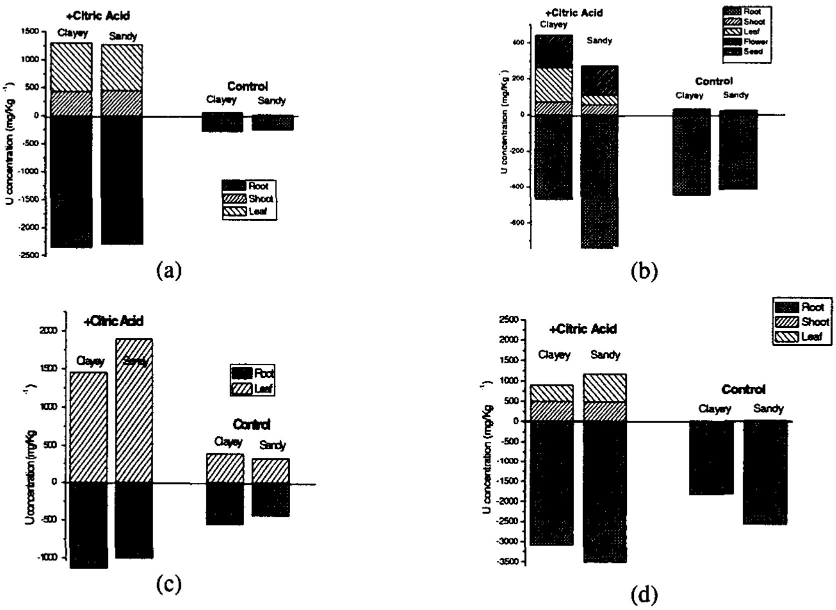


Fig. 1. Uranium concentration of different portions in (a) *B. chinesis* var *oleifera*, (b) *H. annuus*, (c) *B. juncea* and (d) *B. napus* with or without citric acid treatment.

(2) The effects of citric acid

2-1 U concentration in aboveground tissue.

Citric acid increased the U accumulation in aboveground tissue of these four plants with different efficiency. *B. juncea* accumulated the highest U concentration (1456 mg/Kg), while the highest enhancement happened in *B. napus* by 40 times. There is no major difference between different soil types.

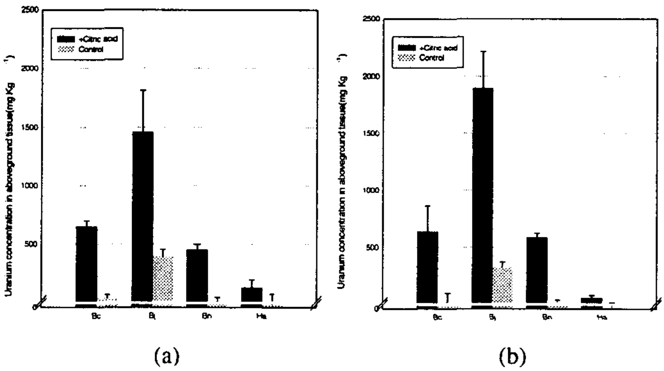
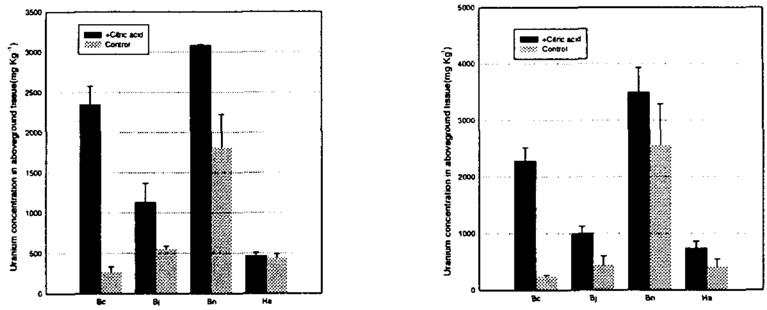


Fig. 2. U concentration with and without citric acid in four species with different efficiency in the (a) clayey and (b) sandy soils.
(Bc: *Brassica chinensis* var. *oleifera*, Bj: *Brassica juncea* L., Bn: *Brassica napus* L., Ha: *Helianthus annuus* L.)

2-2 U concentration in roots

Citric acid increased the U accumulation in roots of these plants with different efficiency except Ha, whose increase was not significant. The degree of enhancement was not as high as in aboveground tissue. *B. napus* accumulated the highest U concentration in roots, while the strongest enhancement of U accumulation in roots was 8.79-time in *B. chinensis* var. *oleifera*. The trends shown in clayey and sandy soils were not significantly different.

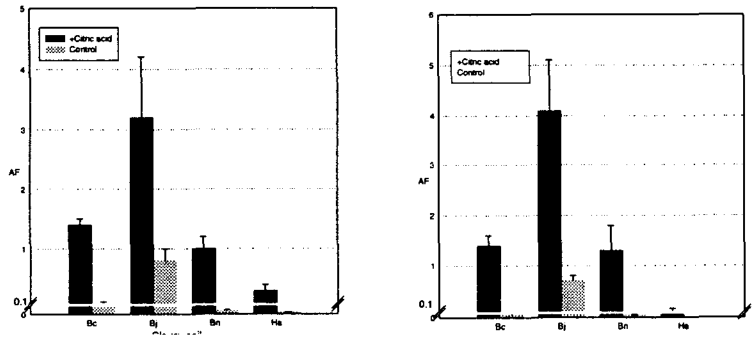


(a) (b)

Fig. 3. U concentration in roots of four species with different efficiency with and without citric acid in (a) clayey and (b) sandy soils.

2-3 AF(Accumulation Factor) of aboveground tissues

The highest AF occurred in *Brassica juncea*. The trends in clayey and sandy soils were the same though the values of AF were different.

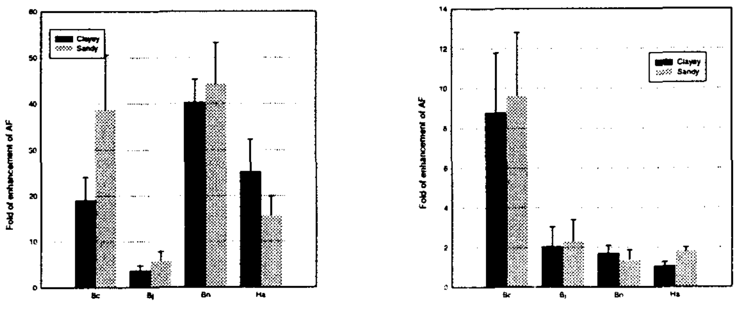


(a) (b)

Fig. 4. AF of aboveground tissue of four species in the (a) clayey and (b) sandy soils.

2-4 Fold of enhancement of AF

The enhancement of AF of aboveground tissue was more significant than in roots. Basically, the trend of enhancement in clayey and sandy soils was the same.



(a) (b)

Fig. 5. The enhancement of AF of (a) aboveground and (b) roots of four species

Conclusion

Citric treatment increased uranium concentration in both shoots and roots, but the increase in roots was not as significant as in shoots. The order of accumulation in portions of plants is root>shoot>leaves>flower or seed. For the aboveground tissue, uranium accumulation was enhanced mostly in *B. napus*, but the highest uranium accumulation happened in *Brassica juncea*, whose bioaccumulation factor increased to 4 from 0.7. *H. annuus* had the lowest uranium accumulated in aboveground tissues. The highest AF occurred in *B. juncea*. The trends in clayey and sandy soils were the same though the values of AF were different. The fold of enhancement of AF of aboveground tissue was more significant than in roots. In general, soil texture did not affect U accumulation.

Acknowledgements

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