Effects of Arsenate, Chromate and Sulfate on Arsenic and Chromium Uptake and Translocation by Arsenic hyperaccumulator *Pteris vittata*

Letúzia M. Oliveira[1,2], Lena Q. Ma[1,3] and Luiz R. G. Guilherme[4],

[1]Soil and Water Science Department, University of Florida, [2]Soil Science Department, Federal Rural University of the Amazon, Belém, Brazil; [3]State Key Laboratory of Pollution Control and Resource Reuse, School of the Environment, Nanjing University, Jiangsu , China; [4]Soil Science Department, Federal University of Lavras, Lavras, Brazil

ABSTRACT

We investigated the effects of arsenate, chromate and sulfate on the uptake and translocation of arsenic and chromium by the arsenic hyperaccumulator *Pteris vittata* L., which was exposed to arsenate (AsV), chromate (CrVI) and sulfate at 0, 0.05, 0.25 and/or 1.25 mM for two weeks in hydroponic system. *P. vittata* accumulated 4,598 and 1,159 mg/kg As in the fronds and roots at 0.05 mM AsV and addition of 0.05 mM CrVI reduced As concentrations to 330 and 1,394 mg/kg. *P. vittata* accumulated 234 and 12,631 mg/kg Cr in the fronds and roots at 0.05 mM CrVI and addition of 0.05 mM AsV reduced Cr concentrations to 46 and 8,073 mg/kg Cr. *P. vittata* effectively took up Cr but was ineffective in Cr translocation. The highest As was 4,211 mg/kg in the fronds and the highest Cr was 42,652 mg/kg in the roots of *P. vittata*. Addition of sulfate increased the uptake and translocation of chromate by 1.6-3 fold and arsenate by 28-68%. This experiment demonstrated that chromate and arsenate inhibited each other whereas sulfate enhanced their uptake and translocation by *P. vittata.*

INTRODUCTION

- Arsenic (As) and chromium (Cr) metals are widely used in the production of pesticides, herbicides, wood preservatives, tanning of skin and hide, chrome plating, dyes and pigments.
- As a result of its extensive use, human exposure and environmental contamination by As and Cr is of concern at many sites around the world.
- Since sites contaminated with As often co-exists with higher levels of other heavy metals such as Cr, Zn, Pb, Cd and Cu, there is an increasing need for developing remediation strategies that consider co-contamination in soil.
- Much research focused on the response of plants to a single metal toxicity. However, in natural soils, plants are often exposed to the accumulative effects of several contaminants.
- The As hyperaccumulator *Pteris vittata* (Chinese bake fern) can accumulate large amounts of As up to 2% in the biomass, with >90% of the accumulated As in the aboveground tissue.
- Its potential in phytoremediation of multiple toxic metals has been investigated. However, the interactive effects of As and Cr on *P. vittata* has not been examined.

OBJECTIVE

The aim of this study was to determine the effects of chromate and sulfate on the uptake and translocation of arsenic and chromium by the arsenic hyperaccumulator *P. vittata.*

MATERIAL AND METHODS

- Healthy plants of *P vittata* with 4-5 fronds were acclimated in 0.2 strength Hoagland solution (HS) for 3 wk.
- After 3 wks, *P. vittata* were exposed to a phosphate- and sulfate-free modified HS , in the presence of arsenate, chromate and/or sulfate for 2 wk in a hydroponic system.
- The concentration of the three oxyanions ranged from 0, 0.05, 0.25 to 1.25mM.
- Oven-dried fern tissues were digested with HNO_3/H_2O_2 hot block procedure with USEPA Method 3050 for As and Cr analysis.
- As and Cr were analyzed by graphite furnace atomic absorption photospectrometry and flame atomic absorption photospectrometry with appropriate spikes and standard reference material (NIST, Gaithersburg, MD).

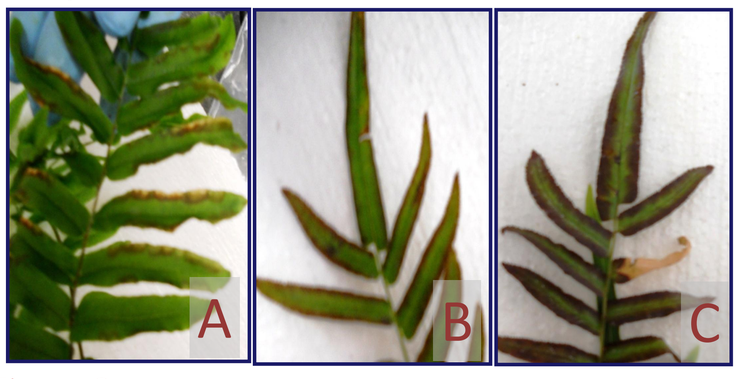


Figure 2. Effect of 0.05 mM As (V) in different Cr(VI) concentrations, (A) 0.05, (B) 0.25 and (C) 1.25 mM on the fronds of *P. vittata.*

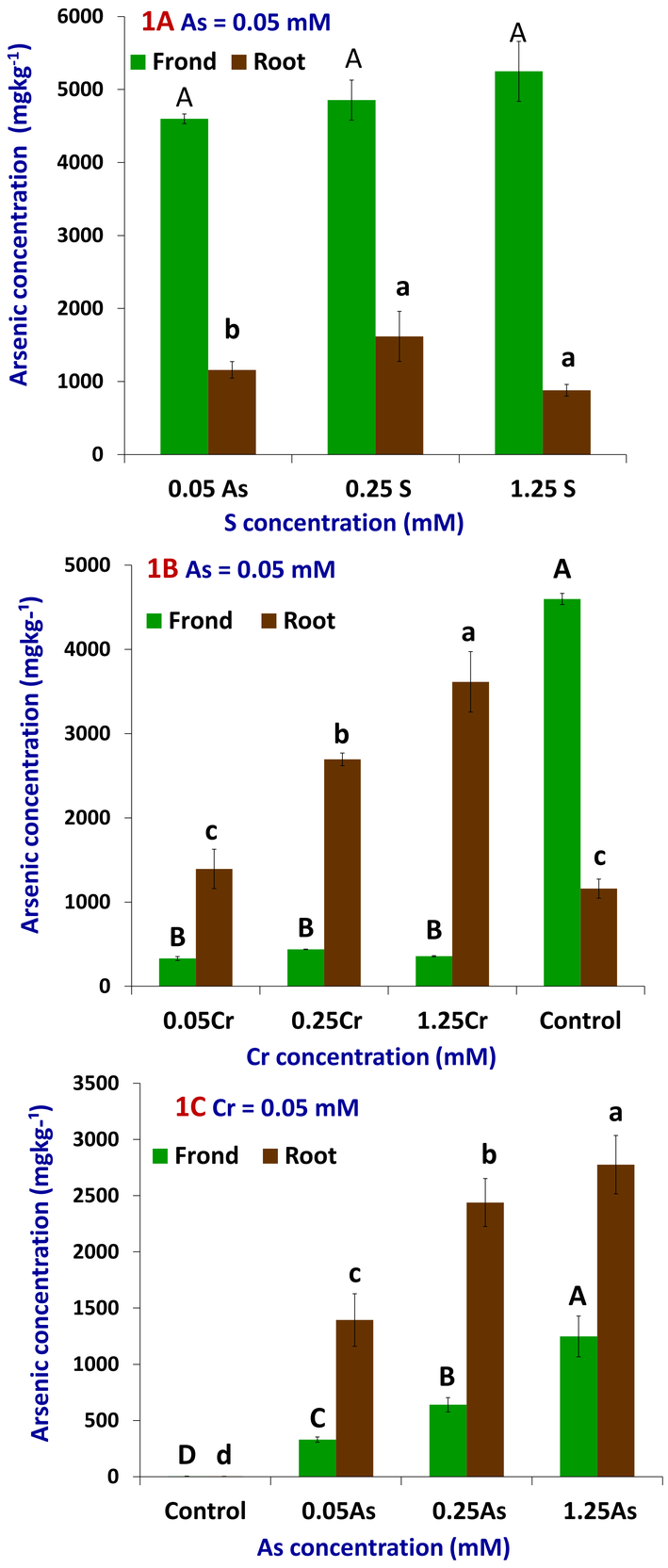


Figure 1A. Sulfate enhanced As uptake and translocation by *P. vittata* (TF increased from 3 to 6)

Figure 1B. Higher Cr concentrations helped more As accumulation in the roots by *P. vittata* (TF decreased from 4 to 0.1)

Figure 1C. Higher As resulted higher As uptake by *P. vittata* but Cr inhibited As translocation (TF = 0.24 – 0.44)

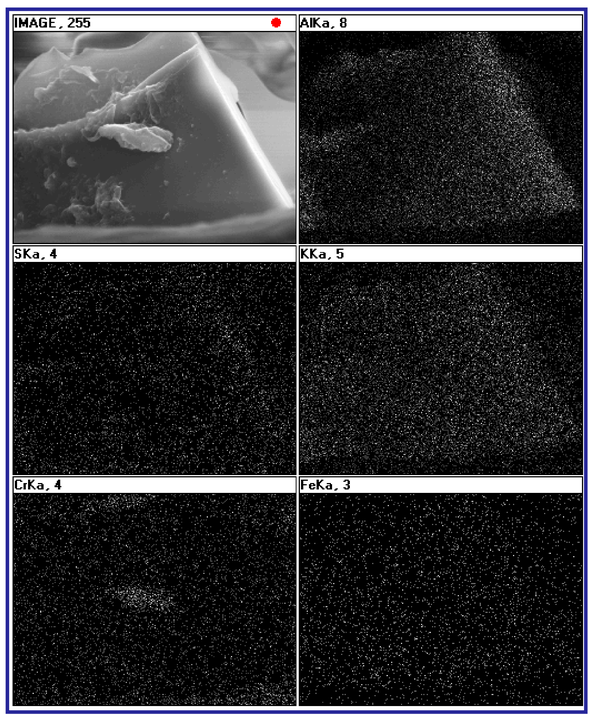
RESULTS

- Concentration of As in *P. vittata* was increased by the addition of sulfate, with total frond accumulation of 5,248 mg kg^{-1} in the presence of 1.25 mM S (Figure 1A).
- *P. vittata* accumulated 4,598 and 1,159 mg kg^{-1} As in the fronds and roots in the presence of 0.05 mM As (Figure 1B); however, addition of 0.05 mM chromate significantly reduced As uptake and translocation, with their concentrations being 330 and 1,394 mg kg^{-1} (Figure 1C).
- *P. vittata* accumulated 234 and 12,631 mg kg^{-1} Cr in the fronds and roots in the presence of 0.05 mM Cr; however, addition of 0.05 mM As significantly reduced Cr uptake and translocation, with their concentrations being 46 and 8,073 mg kg^{-1} Cr (Table 1).

Table 1. Total Cr concentration in fronds and roots of *P. vittata* after exposure to different concentration of As, Cr and S for 15 days.

Solution Concentration (Mm)			Cr Concentration (mg Kg^{-1})	
Arsenic	Chromium	Sulfate	Frond	Root
0	0.05	0	234	12,864
0	0.05	0.25	487	9,632
0	0.05	1.25	707	19,116
0.05	0.05	0	47	8,120
0.05	0.25	0	844	19,648
0.05	1.25	0	2,952	42,901
0.25	0.05	0	92	6,081
1.25	0.05	0	58	4,532

Figure 3. SEM-EDX showing Cr precipitation on the external roots of *P. vittata* as affected 0.05 mM As + 1.25 mM Cr.



CONCLUSION

- Chromate and arsenate inhibited each other while the presence of sulfate enhanced uptake and translocation of both chromate and arsenate by *P. vittata*.
- Chromium accumulation in the roots of *P. vittata* was significantly higher than other plant species reported in the literature.
- As both As and Cr occur as co-contaminants in polluted sites, PV can be used as potential plant for phytoremediation of both metal contaminants.

ACKNOWLEDGE