JSTEI ONLINE JOURNAL
Journal of Science, Technology & Environment Informatics
Journal BiNET Scientific Publication

Volume 01, Issue 02, Article no. 9, pp. 75-80 Jamal Uddin *et al.* 2015
http://www.journalbinet.com/current-issue-jstei1.html
Original Research Paper

Evaluation of *Pteris vittata* as Trap Plant to Mitigate Arsenic from Arsenic Contaminated Soil

A. F. M. Jamal Uddin[1*], M. I. Manirul[2], U. Mayeda[3], M. Z. K Roni[1] and H. Mehraj[1]

Dept. of Horticulture[1]
Dept. of Agricultural Chemistry, Sher-e-Bangla Agricultural University, Dhaka[2]
Dept. of Botany, Jahangirnagar University, Dhaka, Bangladesh[3]

Article Info.

Key Words:

Pteris vittata
Phytoremediation
Arsenic reduction

Received: 05.10.2014
Accepted: 10.02.2015
Published: 18.02.2015

Contact author:
jamal4@yahoo.com

ABSTRACT

An experiment was conducted at Horticultural farm of the Sher-e-Bangla Agricultural University, Bangladesh for phytoremediation of arsenic from soil using Pteris vittata as a trap plant. The experiment was conducted following Completely Randomized Design with three replications. Soil was contaminated with arsenic at different levels by treating @ 0 ppm (A_0), 500 ppm (A_1), 1000 ppm (A_2) and 2000 ppm (A_3) arsenic trioxide (As_2O_3) in pot soil. During the growing period the Pteris vittata as trap plant accumulated 23837.2 ppm, 15332.6 ppm, 1769.9 ppm and 0.9 ppm arsenic from pot soil contaminated with arsenic of A_3, A_2, A_1 and A_0 treatments respectively. Pteris vittata could be use as a possible way to mitigate and or reduce arsenic from soil of arsenic affected areas in Bangladesh.

Citation (APA): Jamal Uddin, A. F. M., Manirul, M. I., Mayeda, U., Roni, M. Z. K. & Mehraj, H. (2014). Evaluation of *Pteris vittata* as Trap Plant to Mitigate Arsenic from Arsenic Contaminated Soil. *Journal of Science, Technology & Environment Informatics,* 01(02), 75–80.

I. Introduction

Bangladeshi people are suffering not only by arsenic contaminated water but also through arsenic contaminated foods as soils might be contaminated with arsenic. Arsenic in food chain could enter into human body through water-soil-plant interactions (Duxbury *et al.*, 2003; Kurosawa *et al.*, 2008). It might be due to high concentrations of arsenic in soils where the foodstuffs are grown. Groundwater for irrigation in crop field is a route of arsenic to enter into food chain. It is important to remove arsenic from contaminated soil to prevent possible impacts, not only in human health but also for ecosystems. Removal of arsenic from soil by phytoremediation technique is a sustainable way to remove arsenic from soil. Trap plants which are used during phytoremediation, usually harvested, transported and disposed off site (Schnoor *et al.,* 2002). Hyper-accumulator plant is capable of growing in soils with very high concentrations of metals, extracting these metals through their roots and concentrating extremely high levels of metals in their tissues. In this case, non edible plants can be used as hyper-accumulator which doesn't causes any hazard to the human health. An arsenic hyper-accumulator plant (*Pteris vittata* L.; Chinese Brake Fern) was discovered by Ma *et al.* (2001) and this plant could be used for removal of arsenic from contaminated soil. Thus, the current pot experiment was conducted to mitigate and or reduce arsenic concentration from soil through *Pteris vittata* as a trap plant.

II. Materials and Methods

Location and period of experiment: The experiment was conducted at the Horticulture farm, Sher-e-Bangla Agricultural University, Bangladesh during the period from July 2012 to October 2012.

Design and treatments: Experiment was carried out following Completely Randomized Design where soil treated with four level of arsenic viz. A_0: Control (0 ppm); A_1: 500 ppm; A_2: 1000 ppm; A_3: 2000 ppm following three replication.

Age of planting materials: Three weeks *Pteris vittata* were transplanted on pot soil.

Forms and source of chemical: Arsenic was applied in the form of Arsenic trioxide (As_2O_3) purchased from Loba Chemie Pvt. Ltd., India.

Fertilization: A ratio of 1:1 well rotten cow dung and soil were mixed and pots were filled 15 days before transplanting.

Intercultural operation: The pot was hand-weeded and watered as needed. No additional fertilizers or soil amendments were added during the growing seasons.

Data collection procedures: Data were collected on leaf number; number of newly emerged leaves, number of fallen/mature leaves, plant height, leaf area, plant leaf biomass, arsenic accumulation on 0.5 mg tested sample of leaf biomass and total arsenic accumulation on plant leaf biomass. Leaf area was measured by non-destructive method using CL-202 Leaf Area Meter (USA).

Chemical analysis for arsenic: Plant biomass was measured by using precision balance after drying. After growing, plants were collected and dried. After drying, leaves were smashed by mortar and pastel machine. The arsenic analysis for was performed in Bangladesh Council of Scientific Research Institute (BCSRI) by using "Atomic Absorption Spectrometer".

Statistical analysis: Collected data were statistically analyzed using MSTAT-C computer package programm. Mean of every treatments were calculated and difference between treatments was evaluated by Least Significance Difference (LSD) test at 5% level of significance (Gomez and Gomez, 1984).

III. Results

Number of leaf

Leaf number of fern species (*Pteris vittata*) showed statistically significant differences among control, 500 ppm, 1000 ppm and 2000 ppm at 15, 30 (Plate 1), 45 and 60 DAT (Figure 1a). Maximum leaf number was observed in A_0 (40.7) whereas minimum from plants grown in 2000 ppm arsenic treated soil (A_3; 14.0) at 60 days after transplanting (DAT) (Figure 1a).

Plant height

Plant height *Pteris vittata* showed statistically significant differences among control, 500 ppm, 1000 ppm and 2000 ppm at 15, 30 (Plate 01), 45 and 60 DAT (Figure 1b). Tallest plant was observed in control (A_0; 60.0 cm) whereas shortest from plants grown at 2000 ppm arsenic contaminated soil (39.3 cm) at 60 DAT (Figure 1b).

Leaf area

Leaf area of *Pteris vittata* showed statistically significant differences among control, 500 ppm, 1000 ppm and 2000 ppm at 15, 30 (Plate 01), 45 and 60 DAT (Figure 1c). Maximum leaf area was observed from control (A_0; 35.0 cm^2) while minimum from the plants grown at 2000 ppm arsenic contaminated soil (A_3; 26.0 cm^2) at 60 DAT (Figure 1c).

Number of newly emerged leaves at 30 DAT

Number of newly emerged leaves at 30 DAT of *Pteris vittata* showed statistically significant differences among control, 500 ppm, 1000 ppm and 2000 ppm (Table 01). Maximum number of newly emerged leaves was found from control (A_0; 12.6) whereas minimum from the plants grown at 2000 ppm arsenic contaminated soil (A_3; 8.3) which was statistically similar with the A_2 (8.7) at 30 DAT (Table 01).

Number of fallen/mature leaves at 30 DAT:

Number of fallen/mature leaves of *Pteris vittata* showed statistically significant differences among control, 500 ppm, 1000 ppm and 2000 ppm (Table 01). Maximum number of fallen leaves were found from plants grown at 2000 ppm arsenic contaminated soil (A_3; 4.6) which was statistically similar with the A_2 (4.0) while minimum from control (A_0; 1.6) (Table 01).

Plant leaf biomass

Plant leaf biomass of *Pteris vittata* showed statistically significant differences among control, 500 ppm, 1000 ppm and 2000 ppm (Table 01). Maximum plant leaf biomass was recorded from control (A_0; 2513.6 mg) whereas the minimum from plants grown at 2000 ppm arsenic contaminated soil (A_3; 1585.0 mg) (Table 01).

Arsenic accumulation in 0.5 mg leaf sample

Maximum arsenic accumulation on leaf was recorded from plants grown at 2000 ppm arsenic treated soil (A_3; 35974.0 ppb) arsenic whereas minimum from arsenic control (A_0; 0.7 ppb) at 0.5 mg leaf sample (Table 01).

Total arsenic accumulation on plant leaves

The total arsenic accumulation by *Pteris vittata* showed statistical significant variation among the different levels of arsenic in soil. Maximum arsenic was accumulated by *Pteris vittata* grown at 2000 ppm arsenic contaminated soil (A_3; 23837.2 ppm) followed by A_2 (15332.6 ppm) and A_1 (1769.9 ppm) whereas minimum from A_0 (1.8 ppm) (Table 01).

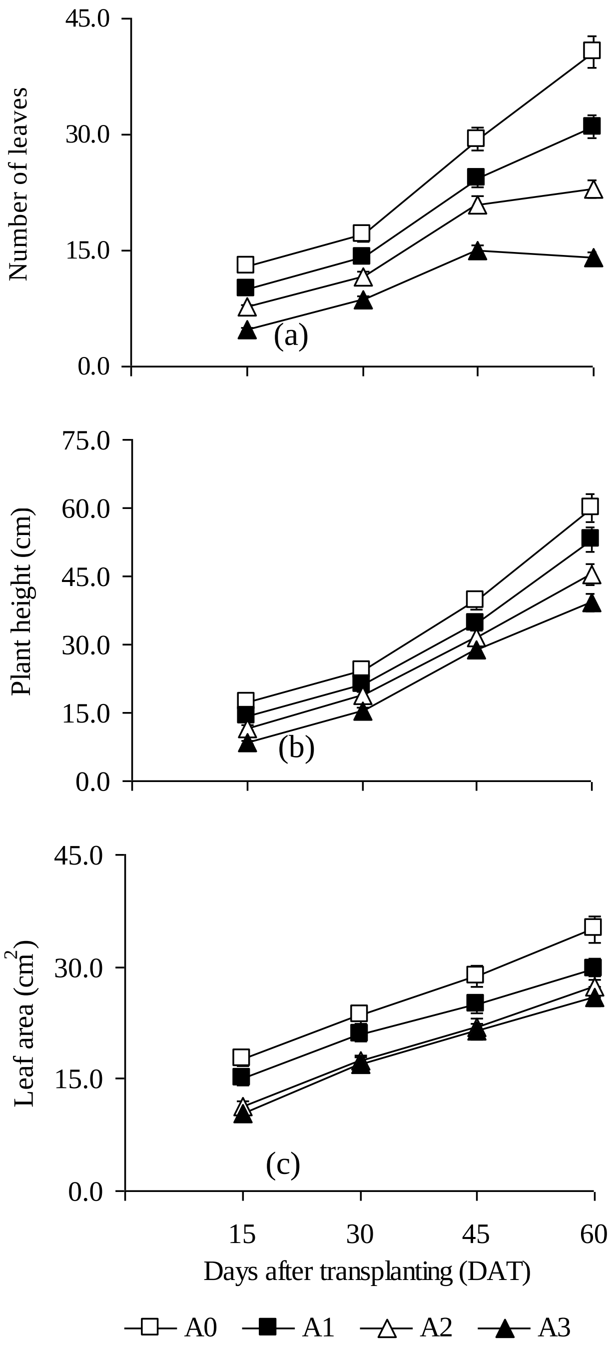

Figure 01. Growth behavior of *Pteris vittata* grown at different concentration arsenic contaminated soil for (a) number of leaves, (b) plant height and (c) leaf area

A_0; Control | A_1: 500 ppm arsenic treated soil | A_2; 1000 ppm arsenic treated soil | A_3; 2000 ppm arsenic treated soil

Plate 01. Plant growth variation grown at different concentration of arsenic treated soil at 30 days after treating

Table 01. Growth behavior and arsenic accumulation of *Pteris vittata* at different level of arsenic in pot soil [x]

Arsenic concentrations	Number of leaves at 30 DAT		Plant leaf biomass (mg)	Arsenic accumulation on 0.5 mg tested sample (ppb)	Total arsenic accumulation on plant leaves (ppm)
	Newly Emerged	Died			
A_0	12.7 a	1.7 c	2513.6 a	0.7 c	0.9 d
A_1	10.3 b	3.3 b	1923.8 c	1840.0 d	1769.9 c
A_2	8.7 c	4.0 ab	2072.3 b	16977.0 b	15332.6 b
A_3	8.3 c	4.7 a	1585.0 d	35974.0 a	23837.2 a
LSD	1.5	0.7	1.5	88.1	44.8
CV%	7.3	10.9	0.1	0.3	0.1

[x] In a column means having similar letter (s) are statistically identical and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

IV. Discussion

From the experiment, it was observed that number of leaves, plant height, leaf area and plant leaf biomass of *P. vittata* reduce with the gradual increase of arsenic concentration. Similar result was also found by Mayda *et al.* (2014). In this study it was found that 2000 ppm arsenic treated soil which was highly toxic for most of the plants but *Pteris vittata* survives very well. This result indicated that *Pteris vittata* grown at 2000 ppm arsenic treated soil capable to uptake maximum 23837.2 ppm amount of arsenic. *Pteris vittata* accumulated arsenic in the fronds (above ground parts) up to 27,000 mg/kg (ppm) dry weight (Wang *et al.*, 2002) and maximum 27829.7 ppm (Mayda *et al.*, 2014). Arsenic induces oxidative stress in fern plants but lower production of thiobarbituric acid-reacting substances in the fronds of *P. vittata* corresponds to its higher arsenic accumulation (Srivastava *et al*, 2005). Antioxidant enzymes are considered to be an important defense system of plants against oxidative stress caused by metals (Weckx and Clijsters, 1996). This arsenic hyper-accumulator has a greater capacity to acclimatize to arsenic stress by more rapidly developing an anti-oxidative defense system than arsenic-sensitive species. *P. vittata* can survive in highly (4000 ppm) arsenic polluted soil by accumulating arsenic (Mayda *et al.*, 2014). *P. vittata* can survive highly arsenic toxic soil and also accumulate arsenic on their different plant parts that may reduce arsenic from soil. Furthermore, these different responses were found to be associated with the levels of arsenic to which the plants were exposed. This study may be very helpful in enhancing the effectiveness of phytoremediation of arsenic-contaminated sites by designing better phytoremediation strategies with the hyper-accumulator *P. vittata*.

V. Conclusion

It was observed that *Pteris vittata* was able to survive on highly arsenic contaminated soil and it accumulated very high level of arsenic during growing period. As it is a non-edible fern, so it can be used as a trap plant for the removal of arsenic from arsenic contaminated soil. Further on field research is highly recommended to validate the finding of this experiment. A more deliberately designed experiment in natural soil systems where incorparation of *Pteris vittata* with edible crops to reclaim arsenic contaminated soil is required and as such protecting arsenic to enter into food chain might be possible in Bangladesh. However, more information is needed at the sub-cellular and molecular levels in order to gain deeper insight into the mechanisms of arsenic toxicity, as well as arsenic accumulation in arsenic tolerant fern species.

VI. References

Abdulla, A. A. & Verkert, K. (1968). Growth flowering and fruit-set of the tomato at higher temperature. Neth. *J. Agric. Sci.* 16: 71-76.

Duxbury, J. M., Mayer, A. B., Lauren, J. G. & Hassan, N. (2003). Food chain aspects of arsenic contamination in Bangladesh: Effects on quality and productivity of rice. *Journal of Environmental Science and Health*, 38(1): 61-69.

Gomez, K. A. & Gomez, A. A. (1984). Statistical procedure for Agricultural Research. Jihn Willey and Sons Ltd. New York. pp. 28-192.

Hartley-Whitaker, J., Ainsworth, G. & Meharg, A. A. (2001a). Copperand arsenate-induced oxidative stress in Holcus lanatus L. clones with differential sensitivity. *Plant, Cell and Environment* 24: 713-722.

Kurosawa, K., Egashira, K., Tani, M., Jahiruddin, M., Zofar A. Z. M. & Zulfikar, M. R. (2008). Groundwater-soil-crop relationship with respect to arsenic contamination in farming villages of Bangladesh – a preliminary study. *Environmental Pollution* 156: 563-565.

Ma, L. Q., komar, K. M., Tu, C., Zhang, W., Cai, Y. & Kennnelly, E. D. (2001). A fern that hyperaccumulates arsenic. Nature(London) 409: 579.

Mayda, U., Akond, M. A., Manirul, M. I., Mehraj, H. & Jamal Uddin, AFM. (2014). Mitigation of Soil Arsenic by Phytoremediation Process. *Int. J. Bus., Soc. and Sci. Res.* 1(2): 87-94.

Schnoor, J. L. (2002). Phytoremediation of soil and groundwater. GWRTAC Technology Evaluation Report TE-02-01.

Srivastava, M., Ma, Q. L., Singh, N. & Singh, S. (2005). Antioxidant responses of hyper-accumulator and sensitive fern species to arsenic. *J. Experimental Botany* 56(415): 1335-1342.

Wang, J., Zhao, F., Meharg, A. A., Raab, A., Feldmann, J. & McGrath, S. P. (2002). Mechanisms of Arsenic Hyperaccumulation in *Pteris vittata*. Uptake Kinetics, Interactions with Phosphate, and Arsenic Speciation. *Plant Physiology* 130: 1552-1561.

Weckx, J. E. J. & Clijsters, H. M. M. (1996). Oxidative damage and defense mechanisms in primary leaves of *Phaseolus vulgaris* as a result of root assimilation of toxic amounts of copper. *Physiologia Plantarum* 96: 506-512.

Citation for this article (APA Style):

Jamal Uddin, A. F. M., Manirul, M. I., Mayeda, U., Roni, M. Z. K. & Mehraj, H. (2014). Evaluation of *Pteris vittata* as Trap Plant to Mitigate Arsenic from Arsenic Contaminated Soil. *Journal of Science, Technology & Environment Informatics,* 01(02), 75–80.

Retrieved February 18, 2015 from http://www.journalbinet.com/current-issue-jstei1.html