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Pteris vittata inter-planting for trapping of arsenic accumulation into potato

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Abstract

An experiment was conducted to trap arsenic accumulation into potato plant by *Pteris vittata* inter-planting. Experiment consisted three different density of the trap plants viz. P_0: No *P. vittata* (control); P_4: four *P. vittata* plant per m² and P_8: eight *P. vittata* plant per m². Inter-planting of four *P. vittata* per m² reduced 95.94 % and eight *P. vittata* per m² reduced 97.01% arsenic accumulation into potato over control. Maximum yield was found from P_4 (359.00 g/plant) which was statistically similar with P_3 (343.80 g/plant) while minimum was found from P_0 (316.50 g/plant). Highest amount of arsenic accumulation was found from P_1 (No *P. vittata* interplanting) in potato tuber flesh (0.20 ppm), tuber peel (5.46 ppm) and plant body (43.74 ppm). *P. vittata* inter-planting (both P_4 and P_8) showed least arsenic accumulation in potato tuber flesh (0.01 and 0.02 ppm in P_4 and P_8 respectively), tuber peel (0.44 and 0.41 ppm in P_4 and P_8 respectively) and plant body (1.52 and 1.40 ppm in P_4 and P_8 respectively) over control. So it can be suggested that inter-planting of *P. vittata* can trap arsenic from soil to enter into food crops. Based on the findings of the current study it can be suggested to inter-plant four *P. vittata* per m² area.

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Introduction

Arsenic is a toxic metalloid in environment, a serious threat and cure to human race because of its capability of causing terrible health hazards to human being (Chaudhuri, 2004; Rahaman *et al.,* 2001). Arsenic-contaminated soils, sediments and sludge are the major sources of arsenic contamination in food chain (Frankenberger and Arshad, 2002). Arsenic contaminated soil caused more arsenic accumulation into food crops than the tolerance level. Phytotoxicity of arsenic is expected to negatively affect plant growth (Kabata-Pendias and Pendias, 1991) and ultimately yield.

Hyperaccumulators are plants that can take up and concentrate more than 0.1% of a given element in their tissue (Brooks, 1998). The first arsenic hyperaccumulator was *Pteris vittata* L. (Ma *et al*., 2001) followed by *Pityrogramma calomelanos* L. (Francesconi *et al*., 2002) and many other species of the *Pteris* genus like *P. cretica* L., *P. longifolia* L., *P. umbrosa* L. and *P. argyraea* L. (Zhao *et al*., 2003) and *P. quadriaurita* L., *P. ryiunkensis* L. and *P. biaurita* (Srivastava *et al*., 2006). *Pteris vittata* is a fast-growing fern and having potentiality to produce relatively high biomass. *P. vittata* can survive highly arsenic contaminated soil (4000 ppm) and accumulate up to 27829.7 ppm arsenic (Mayda *et al*., 2014) and accumulate 23837.2 ppm arsenic from 2000 ppm arsenic contaminated soil (Jamal Uddin *et al*., 2015) into the plant body. Besides *Pteris vittata* is available in Bangladesh. Contribution of food-chain towards arsenic pollution in human is many folds greater than that of drinking water (Roychowdhury *et al*., 2003; Diaz *et al*., 2004). Arsenic accumulation by plants and its translocation to the edible or commercial parts were observed to vary with crops and even among the cultivars of the same crop (Kundu *et al*., 2010; Kundu and Pal, 2009). In case of vegetables, highest As accumulation was observed in potato, arum, amaranth, radish, lady's finger, cauliflower, brinjal where as lower level of As accumulation was observed in beans, green chilli, tomato, bitter guard, lemon, turmeric etc. (Santra *et al*., 2013). As contents of vegetables varied; those exceeding the food hygiene concentration limit of 1.0 mg kg^{-1} (Abedin *et al*., 2002) included kachu sak (*Colocasia antiquorum*) (0.09-3.99 mg kg^{-1}), potatoes (*Solanum tuberosum*) (0.07-1.36 mg kg^{-1}) and kalmi sak (*Ipomoea reptoms*) (0.1-1.53 mg kg^{-1}). Arsenic concentrations in agricultural plants varied from 0.007 to 7.50 mg kg^{-1} (Bhattacharya *et al*., 2010; Dahal *et al*., 2008; Liao *et al*., 2005).

Potato (*Solanum tuberosum* L.) is one of the major vegetable in Bangladesh which ranks second after rice in production (FAOSTAT, 2011). Leafy plants accumulated arsenic by atmospheric deposition, whereas, tuberous plant such as potatoes and carrots accumulated arsenic by both root uptake and atmospheric deposition (Larsen *et al*., 1992). Many researches in Bangladesh had been conducted for arsenic accumulation in potato (Haque *et al*., 2015; Hussain *et al*., 2014) and potato accumulated 0.013-0.390 mg kg^{-1}arsenic in plant (Farid *et al.,* 2003). Potato contaminated by this heavy toxic metal that is ultimately harmful to human health. So it is important to reduce or stop the arsenic accumulation into this vegetable crop. Inter-planting of *P. vittata* with rice plant reduces arsenic entrance into rice plant from soil (Mayda *et al*., 2015). So it may be possible to reduce arsenic accumulation into the potato plant by phytoremediation process using *P. vittata* interplanting into potato field. Concerning these, a study was conducted to lower the arsenic accumulation into potato using *P. vittata* as trap.

Materials and methods

Location and duration of the experiment

An experiment was conducted at Department of Horticulture of the Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh and at the Department of Botany of the Jahangirnagar University, Savar, Dhaka-1342, Bangladesh from October 2013 to April 2014.

Arsenic contaminated soil

Arsenic was applied in form of Arsenic trioxide (As_2O_3) @ 50 ppm at 7 days before planting of potato which was considered as arsenic contaminated soil.

Treatments and design

P. vittata was inter-planted with rice into pot as trap to mitigate arsenic accumulation into potato plant. Experiment consisted three different density of the trap plants viz. P_0: No *P. vittata* (Control); P_4: four *P. vittata* plant per m^2 and P_8: eight *P. vittata* plant per m^2 following completely randomized design with three replication. Trap plants were planted at the time of planting of rice plants.

Pot size

The pot size was 1.5 m in length, 0.5 m in width and 0.5 m in depth.

Data collection

Data were collected on plant height, leaves number, leaf area, number of stems per plant, stem diameter, number of tubers, average weight of individual tuber, yield, arsenic accumulation by tuber flesh and peel, arsenic accumulation by plant body, arsenic accumulation by *Pteris vittata* and protection of arsenic accumulation into potato by *P. vittata* over control.

Chemical analysis for arsenic

Plant biomass was measured by using precision balance after drying. After growing, plants were collected and dried. After drying, samples were smashed by mortar and pastel machine. The arsenic analysis for was performed by using "Atomic Absorption Spectrometer", where use of argon for carrier gas and arsenic was melted by 925°C; was approved by ISO organization in Bangladesh Council of Scientific Research Institute (BCSIR), Dhaka, Bangladesh.

50 times dilution

5 ml conc. HCl was taken at 50 ml volumetric flasks for transferring arsenic into arsenic trioxide and a little bit of distilled water was added. Then 1ml solution was taken very carefully from each volumetric flask to avoid bubble and KI (01 gm) wash added in solution with 150 ml distilled water. After that 0.5 gm sample was taken in volumetric flask and mixed distilled water up to 50 ml and solution turned into yellow color. Another volumetric flask made blank solution, where contain only HCl, KI and distilled water for arsenic analysis.

1000 time dilution

2 ml solution was taken into 500 volumetric flasks, mixed with distilled water up to 500 ml and shaken very carefully. Then, 05 ml solution was taken into 250 ml volumetric flask and mixed with distilled water up to 250 ml. Again, 05 ml solution from 250 ml solution was taken into 25 ml volumetric flask then 2.5 ml HCl and 2.5 ml KI was added and mixed distilled water, shaking was done very smoothly until turn it into yellow color. Standard solution arsenic was added with HCl 2, 5, 10, 15, 20 ppb respectively.

5000 time dilution

Similar to the 1000 time dilution. But 04 ml solution was taken in case of 2 ml. 05 ml HCl and KI was added into 5000 ml volumetric flask, solution was made into 25 ml and 05 ml was taken in flask.

Statistical analysis

Data were statistically analyzed using MSTAT-C computer programme. Difference between treatments was assessed by Least Significance Difference (LSD) test at 5% level of significance (Gomez and Gomez, 1984).

Result and discussion

Plant height and leaves number

Tallest plant was found from P_4 (35.7 cm) and shortest from P_0 (33.1 cm) at 90 DAP (Figure 1a). Maximum leaves number was found in P_4 (46.96) and minimum from P_0 (44.92) at 90 DAT (Figure 1b). Arsenic is toxic to most plants at higher concentration (Marin *et al.*, 1993) and inter-planting of *P. vittata* caused better plant growth by reducing soil arsenic toxicity for rice (Mayda *et al.*, 2015). It interfered with metabolic processes and inhibited plant growth and development through arsenic induced phytotoxicity.

Leaf area

Leaf area of potato was significantly affected by density of *P. vittata* inter-planting. The maximum leaf area was found from P_4 (1.16 cm^2) whereas lowest leaf area was found from P_0 (1.10 cm^2) (Table 1). Decreased in leaf area was found in control than that of the other treatments. It notified that inter-planting of *P. vittata* reduced arsenic toxicity for potato plants. Arsenic reduced the leaf area index of potato (Juzl and Stefl, 2002). *P. vittata* is an arsenic-hyper accumulating fern and can be used in arsenic remediation from arsenic-contaminated soils (Jamal Uddin *et al.*, 2015; Mayda *et al.*, 2014).

Number of stems and stem diameter

Number of stems was significantly affected by density of *P. vittata* inter-planting. Maximum number of stems was found in P_4 (3.61/hill) whereas minimum from P_0 (3.51/hill) (Table 1). Excess arsenic in soil inhibited plant growth (Carbonell *et al.*, 1995) and from present study it was found that *P. vittata* inter-planting was not inhibited the potato growth compared to control. Stem diameter was significantly affected by density of *P. vittata* inter-planting. Maximum stem diameter (0.43 cm) was recorded from P_4 and minimum stem diameter (0.38) was recorded from P_0 (Table 1). It is possible to remove arsenic by Chinese Brake Fern (*P. vittata*) from an arsenic contaminated soil (Jamal Uddin *et al.*, 2015; Mayda *et al.*, 2014; Mandal *et al.*, 2012) and for this reason *P. vittata* inter-planting may resulted better stem diameter over control.

Number of tubers, average weight of individual tuber and yield

Number of tillers per plant was significantly affected by density of *P. vittata* inter-planting. Maximum number of tubers was recorded from P_4 (16.24/hill) and minimum number of tubers was recorded from P_0 (14.21/hill) (Table 1). Average weight of individual tuber was also significantly affected by density of *P. vittata* inter-planting. Maximum weight of individual tuber was recorded from P_0 (22.27 g) and minimum from P_4 and P_8 (22.11 g and 22.10 g respectively) (Table 1). This study indicate *that P. vittata* affect the average weight of individual tuber. *Pteris vittata* uptake arsenic and render arsenic enter into food parts. When plants were exposed to excess arsenic either in soil or in solution culture, they exhibited toxicity symptoms (Johan *et al.*, 2003) but result from the current study suggested that *Pteris vittata* inter-planting may responsible for reducing arsenic toxicity. Yield of potato was significantly affected by density of *P. vittata* inter-planting. Highest yield was found from P_4 (359.00 g/plant) and lowest yield was found from P_0 (316.50 g/plant) (Table 1).

Table 1. Potato responses to *Pteris vittata* density at different attributes.

Treatments	Leaf area (cm^2)		Number of stems/hill		Stem diameter (cm)		Number of tubers/hill		Avg. weight of individual tuber (g)		Yield/plant (g)	
P_0	1.10	c	3.51	c	0.38	c	14.21	c	22.27	a	316.50	c
P_4	1.16	a	3.61	a	0.43	a	16.24	a	22.11	b	359.00	a
P_8	1.12	b	3.55	b	0.41	b	15.55	b	22.10	b	343.80	b
LSD0.05	0.02		0.02		0.02		0.48		0.12		9.46	
CV%	0.59		0.37		1.41		1.36		0.25		1.23	

P_0 = Control (without *Pteris vittata*), P_4 = 4 *Pteris vittata* per square meter, P_8 = 8 *Pteris vittata* per square meter

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..

Arsenic accumulation

Arsenic accumulation by potato tuber flesh and peel was significantly affected by density of *P. vittata* inter-planting. Highest arsenic accumulation by tuber flesh was found from P_0 (0.20 ppm) and lowest from P_4 (0.01 ppm) (Table 2). Maximum arsenic accumulation was observed in potato, arum, amaranth, radish, lady's finger, cauliflower, brinjal where as lower level of As accumulation was observed in beans, green chilli, tomato, bitter guard, lemon, turmeric etc. due to the As-contaminated irrigation water (Santra *et al.*, 2013). Highest arsenic accumulation in tuber peel was found from P_0 (5.46 ppm) and lowest from P_4 and P_8 (0.44 ppm and 0.41

ppm respectively) whereas P_4 and P_8 were found to be statistically identical (Table 2). The present experiment indicates that *P. vittata* helpful to potato tuber uptake low amount of arsenic. *P. vittata* is capable of accumulating arsenic from contaminated sites, and a single harvest per year yields the greatest arsenic removal. Arsenic accumulation by plant body was significantly affected by density of *P. vittata* inter-planting. Highest accumulation was found from P_0 (43.74 ppm) and lowest from P_4 and P_8 (1.52 ppm and 1.40 ppm respectively) while P_4 and P_8 were statistically identical (Table 2).

Table 2. Arsenic accumulation in tuber flesh, tuber peel, plant body, *Pteris vittata* and protection percentage into potato as affected by different density.

Treatments	Arsenic accumulation (ppm)							Protection of arsenic accumulation into potato (%)
	Tuber flesh		Tuber peel		Plant body		*P. Vittata*	
P_0	0.20	a	5.46	a	43.74	a		
P_4	0.01	c	0.44	b	1.52	b	47.40	95.94
P_8	0.02	b	0.41	b	1.40	b	47.93	97.01
LSD0.05	0.002		0.42		0.41			
CV%	7.53		8.75		1.15			

[X]P_0 = Control (without *Pteris vittata*), P_4 = 4 *Pteris vittata* per square meter, P_8 = 8 *Pteris vittata* per square meter.

[Y]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.

As contents of vegetables varied; those exceeding the food hygiene concentration limit of 1.0 mg kg^{-1} (Abedin *et al.*, 2002) included kachu sak (*Colocasia antiquorum*) (0.09-3.99 mg kg^{-1}), potatoes (*Solanum tuberosum*) (0.07-1.36 mg kg^{-1}) and kalmi sak (*Ipomoea reptoms*) (0.1-1.53 mg kg^{-1}). *Pteris vittata* accumulate high amount of arsenic P_8 (47.93 ppm) and P_4 (47.40 ppm) (Table 2) which was found to reduce 97.01% and 95.94% arsenic accumulation into potato. Similarly reduction of arsenic accumulation by *P. vittata* inter-planting was also found in rice (Mayda *et al.*, 2015).

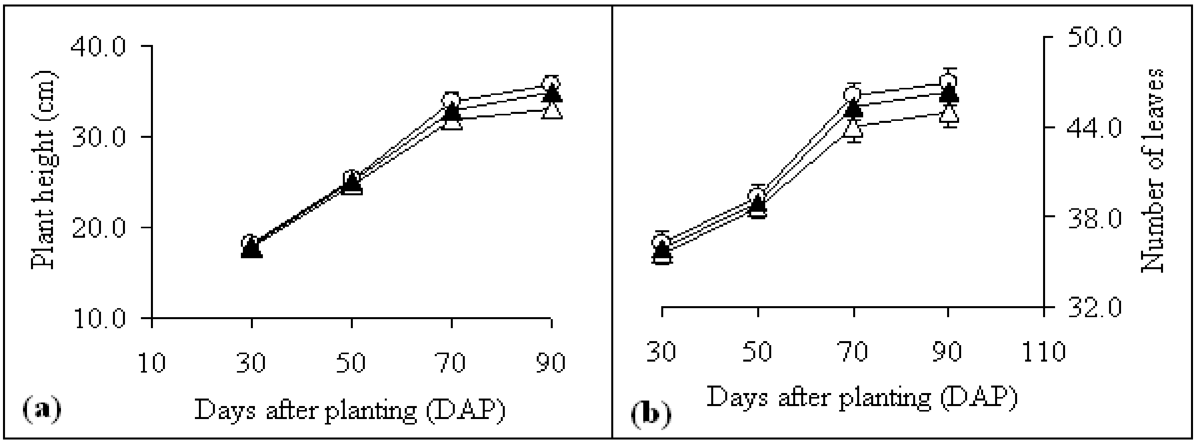

Fig. 1. Effect of *Pteris vittata* density on (a) plant height and (b) number of leaves of potato at different days after planting (DAP).

Here, P_0 = Without *Pteris vittata*, P_4 = Four *Pteris vittata*/m^2, P_8 = Eight *Pteris vittata*/m^2.

Hyperaccumulators are plants that can take up and concentrate greater than 0.1% of a given element in their tissue. Recently, an arsenic hyperaccumulator, *Pteris vittata* (Chinese brake fern), was discovered (Ma *et al.*, 2001). This arsenic hyperaccumulator may offer an alternative to more traditional remediation technologies for arsenic contaminated soils.

Conclusion

Inter-planting of *P. vittata* with potato dramatically reduced arsenic accumulation into the potato flesh, peel and plant body while *P. vittata* accumulated most of the arsenic from soil. Current study confirmed that it is possible to trap arsenic accumulation into potato by inter-planting of *P. vittata*. However, more experiment should be conducted to clarify this finding.

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