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EFFECT OF RICE HUSK ON ARSENIC ACCUMULATION IN POTATO PLANT UNDER DIFFERENT LEVELS OF ARSENIC TREATED SOIL

T.S. Roy[1], M.S. Rahman[2], M. Mostofa[3], M. Nahid[4], M.G. Khatun[5] and M.A. Razzaque[4]

[1]Department of Agronomy, [2]Department of Bio Chemistry, [4]Department of Agricultural Chemistry, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Bangladesh
[3]Tuber Crops Research Centre, Bangladesh Agricultural Research Institute, Gazipur
[5]Institute of Seed Technology, Faculty of Agriculture, Sher-e-Bangla Agricultural University
Corresponding E-mail: tuhinsuvraroy@sau.edu.bd

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Abstract

A pot experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Dhaka during the period from November, 2020 to May, 2021 to find out the effect of rice husk as an bio-adsorbent to decontaminate As toxicity in potato. The experiment consisted of two factors. Factor A: Arsenic levels (4) *viz*., As_0: control (0 mg As kg^{-1} soil), As_1: 20 mg As kg^{-1} soil, As_2: 40 mg As kg^{-1} soil, and As_3: 60 mg As kg^{-1} soil. Factor B: Rice husk levels (4) *viz*., R_0: control (0 g kg^{-1} soil), R_1: 20 g kg^{-1} soil, R_2: 40 g kg^{-1} soil and R_3: 60 g kg^{-1} soil. The experiment was laid out in a factorial randomized complete block design with three replications. Results revealed that As and/or rice husk had significant effect on arsenic load in different plant parts of potato t. Arsenic content in potato tuber flesh, peel, haulm and root gradually increased with the increase of its levels. On the contrary, As content in plant parts decreased with increasing rice husk levels. The soil treated with As_1R_3 exhibited As accumulation in tuber flesh (0.1070 mg kg $^{-1}$ fresh weight) and peel (0.443 mg kg $^{-1}$ FW), respectively. As load in different plant parts was in the sequence: root > haulm > tuber peel > tuber flesh. Although, the least As loading in tuber flesh was observed in As_1R_1, As_1R_2, As_1R_3 (range 0.1258-0.1070 mg kg^{-1} FW) which also showed higher productivity (range 402.67 - 416.67 g $plant^{-1}$), but the treatment combination of As_1R_1 may be suitable for safe potato cultivation in lower level As contaminated soil. Therefore, potato growers can grow potato up to 20 mg As kg^{-1} contaminated soil treated with 20 g rice husk kg^1 soil, which contains safe As load than the critical one (0.157 mg As kg $^{-1}$ FW) for human consumption. So, application of rice husk for potato cultivation may a good option to reduce the arsenic hazards in lower arsenic endemic areas.

Introduction

Arsenic (As), the toxic metalloid element, causes terrible health hazards to human beings. Around 110 million people in South and South-east Asia are suffering from this problem, the magnitude is considered to be the maximum in Bangladesh (Sanyal, 2005). As-contaminated groundwater used for irrigation may pose serious health hazard to people eating food from irrigated crops (Williums *et al*., 2006). Roychowdhury *et al*. (2003) reported that the contribution of food-chain towards As pollution in human is many folds greater than that of the drinking water. The acute minimal lethal dose of As in adults is estimated to be 1 $mg^{-1}kg^{-1}day^{-1}$ (Das *et al*., 2004). Recent studies suggest that a number of crops and vegetable plant species accumulate significant amount of As.

The higher As accumulation was observed in aroids, amaranth, radish, lady's finger, cauli flower, and brinjal, whereas the lower level of As accumulation was observed in potato, beans, green chili, tomato, bitter guard, and turmeric, etc. due to the As-contaminated irrigation water (Mandal and Suzuki, 2002). As concentration in plants varied from less than 0.01 to about 5.0 g kg^{-1}, whereas the food safety limits of less than 1.0 mg kg^{-1} (Abedin *et al.*, 2002). Potato is a world's single most important tuber crop with a vital role in the global food system and food security (Brown, 2005). Bangladesh was the world's 8th largest producer of potatoes with a total production of about 97,44,412 million ton (FAOSTAT, 2019). Potato consumption as processed and fresh food is also increasing considerable in Bangladesh. People living in As affected areas are consuming contaminated potatoes that creates serious health problems. Bio-sorption technology includes metal removal performance for industrial waste water. This process is economical and eco-friendly compare with others (Lee *et al*., 2009). It is a conventional technique for metal remediation. Bio sorption uses adsorbents derived from non-living biomass like sawdust, rice husk, egg shell etc. and removes toxic metals from industrial waste water and contaminated soil (Lee *et al*., 2013). However, it is necessary to search for appropriate agricultural management practices to minimize the Arsenic content in tubers. In this context, the present investigation was mainly axed of As accumulation in potato through rice husk application.

Materials and Methods

The pot experiment was conducted at the research field of Sher-e-Bangla Agricultural University. The location of the site is 23.74^0N latitude and 90.35^0E longitude with an elevation of 8.2 meter from sea level. The experiment consisted of two factors. Factor A: Arsenic levels (4) *viz*., As_0: control (0 mg As kg^{-1} soil), As_1: 20 mg As kg^{-1} soil, As_2: 40 mg As kg^{-1} soil, and As_3: 60 mg As kg^{-1} soil. Factor B: Rice husk levels (4) *viz*., R_0: control (0 g kg^{-1} soil), R_1: 20 g kg^{-1} soil, R_2:40 g kg^{-1} soil and R_3: 60 g kg^{-1} soil. The two factors experiment was laid out in a randomized complete block design with five replications. Rice husk was collected from a rice mill. The collected soil was sandy loam. Soil pH and organic carbons were 5.8 and 0.44%, respectively. The experimental soil of basket was fertilized with a recommended dose of N, P, K, S, Zn, B and cowdung @ 575 µg, 345 µg, 750 µg, 108 µg, 18 µg, 8.75 µg and 50 g, respectively, per 10 kg soil (Mondal *et al*., 2011). The certified grade potato tubers of var. Courage were used as planting material. Collected seed potato tubers were kept at room temperature to facilitate sprouting. The properly sprouted, healthy, and uniform sized (60-70 g) seed potato tubers were planted according to treatment and an entire Potato planted in each basket. Seed potatoes were planted on an average 5-6 cm depth in the basket. All the intercultural operations and plant protection standards were taken as per Tuber Crops Research Centre recommendation. Haulm (shoot of potato plant) pulling was done at 90 DAP when the majority of plants showed senescence and the tops started drying. After haulm pulling, the tubers were kept under the soil for 10 days for skin hardening. The Potatoes of each basket were separately harvested, bagged, tagged and brought to the laboratory for further analysis. All yield contributing parameters were calculated as per Tuber Crops Research Centre, BARI, Bangladesh.

Potatoes were harvested and packed with labeled net bags according to treatment. Haulm (above ground portion), roots and tuber were collected as per treatment. After peeling the tuber, both peel and flesh samples were separated into different labeled packets. The labeled packets were immediately sent to the Analytical Laboratory of Bangladesh Council of Scientific and Industrial Research (BCSIR), Dhaka, where Arsenic was determined with an Atomic Absorption Spectrophotometer (HG-AAS) following USEPA method 1632 (USEPA, 2001). The data obtained for different characters were statistically analyzed to observe the significant difference among different treatments. The analysis of variance of all the recorded parameters performed using Statistics-10 software. The difference of the means value was separated by Least Significant Difference (LSD) at 5% level of probability (Gomez and Gomez, 1984).

Results and Discussion

Arsenic accumulation in tuber flesh

The Arsenic load in tuber flesh increased with increasing Arsenic level (Table 1). A higher concentration of Arsenic in soils also created higher absorption of this element by plant parts, which were damaged and restricted plants growth (Onken and Hossner, 1995). On the contrary, Arsenic load in tuber flesh decreased with increasing the rate rice husk application (Table 2). The treatment combination of different Arsenic and rice husk levels significantly influenced Arsenic load in tuber flesh (Table 3). The least amount of Arsenic load in tuber flesh was observed in As_1R_3 (0.1070 mg kg^{-1} FW), whereas, the maximum was recorded in As_3R_0(0.5063 mg kg^{-1} FW).

The overall Arsenic accumulation result showed that high bio adsorbent in soil that occurred more bio sorption process as a result increasing of rice husk levels in a particular concentration of Arsenic. Arsenic content in tuber flesh drastically decreased by only increasing of rice husk level. Rice husk acted as a bioadsorbent in soil and breakdown by microorganism with the presence of soil water and produced cellulosic waste materials *viz.*, acetamido, amido, amino, alcoholic, carbonyl, phenolic, sulphydryl groups, etc., by microorganism with the presence of soil water adsorb Arsenic by rice husk from the soil solution and make an intermediate complex between soil colloid and Arsenic. Rice husk has a close affinity for heavy metal remediation from the aqueous solutions (Sud *et al*., 2008). As a result, when rice husk (bio-adsorbent) levels increased in soil occurred more biosorption process, then the concentration of As decreased in tuber flesh (Table 3).

Table 1. Effect of Arsenic levels on Arsenic accumulation (mg kg^{-1} FW) in different plant parts of potato at harvest

Treatments	Tuber flesh	Tuber peel	Haulm	Root
As_0	0.0000 d	0.0000 d	0.0000 d	0.0000 d
As_1	0.1983 c	0.6938 c	4.2545 c	5.1320 c
As_2	0.2623 b	1.4469 b	5.8308 b	9.0067 b
As_3	0.3739 a	2.0305 a	8.2600 a	12.821 a
$LSD_{(0.05)}$	0.0103	0.287	0.6987	4.114
CV (%)	5.94	9.30	18.27	7.32

In a columns means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of probability. As_0: Control, As_1: 20 mg As kg^{-1} soil, As_2: 40 mg As kg^{-1} soil, As_3: 60 mg As kg^{-1} soil.

Arsenic accumulation in tuber peel

Arsenic content of tuber peel varied significantly with different Arsenic levels. The Arsenic content of the tuber peel gradually increased with increasing Arsenic levels (Table 1). The minimum Arsenic load in tuber peel was recorded in As_1 (0.6938 mg kg^{-1} FW/), while the maximum in As_3 (2.0305 mg kg^{-1} FW/). Arsenic concentration in Potato peel was higher than Arsenic concentration in Potato flesh (Norton *et al*., 2013). Arsenic load in tuber peel varied significantly with different rice husk levels. The Arsenic load in tuber peel gradually decreased with increasing rice husk levels (Table 2). The lowest Arsenic load in tuber peel was recorded in R_3 (0.5795 mg kg^{-1} FW) while the maximum in R_0 (1.7423 mg kg^{-1} FW).

Table 2. Effect of Rice husk levels on Arsenic accumulation (mg kg^{-1} FW) in different plant parts of potato cv. Courage

Treatments	Tuber flesh	Tuber peel	Haulm	Root
R_0	0.3592 a	1.7423 a	6.6577 a	9.1834 a
R_1	0.1982 b	1.0799 b	4.3503 b	7.0293 b

R_2	0.1604 c	0.7694 c	3.5818 c	5.8994 c
R_3	0.1167 d	0.5795 d	3.7555 bc	4.8472 d
$LSD_{(0.05)}$	0.103	0.287	0.6987	4.114
CV (%)	5.94	9.30	18.27	7.32

In a columns means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of probability. NS= Non-significant, R_0-= 0 g rice husk kg^{-1} soil, R_1 =20 g rice husk kg^{-1} soil, R_2= 40 g rice husk kg^{-1} soil, R_3= 60 g rice husk kg^{-1} soil

The treatment combination of Arsenic and rice husk levels significantly influenced the arsenic load in potato peel (Table 3). The maximum Arsenic load in tuber peel was observed in As_3R_0 (3.8277 mg kg^{-1} FW) while no accumulation was found in As_0 R_0 followed by As_0 R_1, As_0R_2 and As_0R_3 because no Arsenic was treated in soil and the minimum Arsenic load was recorded in As_1R_3 (0.3443 mg kg^{-1} FW). Table 3 also showed that only by increasing of rice husk level, the accumulation of Arsenic decreased in tuber peel. Rice husk acted as a bioadsorbent in soil and breakdown by microorganism with the presence of soil water and produced cellulosic waste materials *viz.*, acetamido, amido, amino, alcoholic, carbonyl, phenolic, sulphydryl groups, etc. by microorganism with the presence of soil water adsorb Arsenic by rice husk from the soil solution and make an intermediate complex between soil colloid and Arsenic. Rice husk has a close affinity for heavy metal remediation from the aqueous solutions (Sud *et al*., 2008). High bioadsorbent in soil occurred more bisoroption process as a result increasing of rice husk levels in a particular concentration of Arsenic, Arsenic content in tuber peel decreased. The experimental results exhibited that Arsenic concentration in potato peel was always higher than Arsenic concentration in potato flesh. Norton *et al*. (2013) also stated similar trends of Arsenic load in tuber flesh and peel.

Arsenic accumulation in haulm

Arsenic accumulation in haulm (above ground shoot) varied significantly due to different Arsenic levels. Table 1 showed that the Arsenic load in haulm progressively increased with increasing Arsenic levels due to a higher concentration of Arsenic in soils also creates higher absorption of this element by haulm. Onken and Hossner (1995) also indicated similar opinion. Arsenic accumulation in haulm varied significantly with different rice husk levels (Table 2). The result also demonstrated that Arsenic load in haulm decreased with increasing rice husk level. The combination of Arsenic and rice husk levels showed significant effect on Arsenic loading by haulm (Table 3). The maximum Arsenic load in haulm was observed in As_3R_0 (13.360 mg kg^{-1} FW) while no accumulation was found in As_0 R_0 followed by As_0 R_1, As_0R_2 and As_0R_3 because no Arsenic was treated in soil and the minimum Arsenic load was recorded in As_1R_2 (3.0477 mg kg^{-1} FW).

Arsenic accumulation in root

Accumulation of Arsenic in root differed significantly due to different levels of Arsenic were treated in soil (Table 1). The amount of Arsenic load in root progressively increased with increasing Arsenic levels. On the contrary, the accumulation of Arsenic gradually decreased with increasing rice husk levels (Table 2). The combined effect of Arsenic and rice husk was also significant on Arsenic loading by root. Table 9 showed that the maximum Arsenic load in root was detected in As_3R_0 (17.950 mg kg^{-1} FW) while no accumulation was found in As_0 R_0 followed by As_0 R_1, As_0R_2 and As_0R_3 because no Arsenic was treated in soil and the minimum Arsenic load was recorded in As_1R_3 (3.4497 mg kg^{-1} FW).

Table 3. Combined effect of Arsenic and rice husk on Arsenic accumulation (mg kg^{-1} FW) in different plant parts of potato at harvest

Treatment combinations	Tuber flesh	Tuber peel	Haulm	Root
As_0 R_0	0.0000 h	0.0000 k	0.0000 g	0.0000 j
As_0 R_1	0.0000 h	0.0000 k	0.0000 g	0.0000 j

As_0R_2	0.0000 h	0.0000 k	0.0000 g	0.0000 j
As_0R_3	0.0000 h	0.0000 k	0.0000 g	0.0000 j
As_1R_0	0.4407 c	1.0807 g	5.5943 cd	7.4513 f
As_1R_1	0.1258 g	0.8343 h	3.8697 ef	5.2343 g
As_1R_2	0.1223 g	0.5157 i	3.0477 f	4.3927 h
As_1R_3	0.1070 g	0.3443 j	4.5063 de	3.4497 i
As_2R_0	0.4900 a	2.0610 b	7.6760 b	11.332 c
As_2R_1	0.2070 e	1.6227 d	5.7973 cd	9.2470 d
As_2R_2	0.1923 e	1.2183 f	5.1173 cde	8.1340 ef
As_2R_3	0.1600 f	0.8857 h	4.7327 de	7.3133 f
As_3R_0	0.5063 a	3.8277 a	13.360 a	17.950 a
As_3R_1	0.4627 b	1.8627 c	7.7343 b	13.636 b
As_3R_2	0.3270 d	1.3437 e	6.1623 c	11.071 c
As_3R_3	0.1997 e	1.0880 g	5.7830 cd	8.6260 de
$LSD_{(0.05)}$	0.0207	0.573	1.3973	8.228
CV (%)	3.95	9.30	18.27	7.32

In a colums means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of probability. NS= Non-significant, As_0: Control, As_1: 20 mg As kg^{-1} soil, As_2: 40 mg As kg^{-1} soil, As_3: 60 mg As kg^{-1} soil.
R_0= 0 g rice husk kg^{-1} soil, R_1= 20 g rice husk kg^{-1} soil, R_2 =40 g rice husk kg^{-1} soil, R_3 = 60 g rice husk kg^{-1} soil

Accumulation pattern of Arsenic in potato plant parts

The maximum accumulation of Arsenic was detected in the root (53.6%) as compared to those of other plant parts (Figure 1). The roots contained a higher Arsenic load than haulm> tuber peel > tuber flesh. Haulm accumulated 43.6% Arsenic, whereas, tuber only 3.8%. Finally, tuber flesh (1.5%) accumulated Arsenic very low concentration of this toxic metalloid as compared to all other plant parts. Comparison of Arsenic loading of different plant parts clearly showed that translocation of Arsenic in edible part is relatively lower than the any other plant parts. Generally, the distribution arsenic load in plant parts is found to be in the order: root> haulm>tuber. Abedin *et al*. (2002) and Sanyal (2005) also observed similar order for Arsenic loading in potato plant parts.

A plant can only uptake Arsenic as As (III) and As (V). However, it is possible when Arsenic complex hydrolysis in soil solution and make As (III) and As (V) but when bioadsorbent like rice husk was present in the soil the As (III) and As (V) made a bond with different cellulosic organic complex with soil colloid and produced intermediate complex among Arsenic, cellulosic compound and soil colloid. In this regard, the plant could not accumulate Arsenic. Rice husk has a close affinity for heavy metal remediation from the aqueous solutions (Sud *et al*., 2008). The sorption of heavy metals towards biomaterials is attributed to their constituents, which are mostly carbohydrates, proteins, and phenolic compounds because they carry functional groups, for example, amines, carboxyls, and hydroxyls, which can bind to the metal ions (Choi and Yun, 2006).

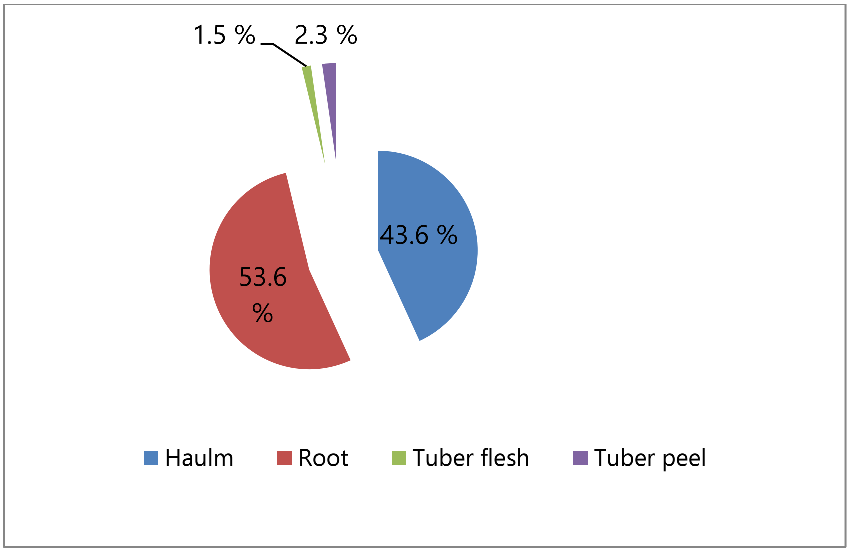

Fig. 1. Arsenic accumulation pattern of potato (average value of all treatments).

Conclusion

Rice husk had significant effect on arsenic accumulation in plant parts of potato. The soil treated with 60 g Rice husk kg^{-1} soil, decreased 67.51 and 66.73% arsenic accumulation through tuber flesh and peel, respectively compared to without rice husk. Among the treatment combinations, although As_1R_1, As_1R_2 and As_1R_3 were found suitable but As_1R_1 was the appropriate because, in this combination, tuber flesh accumulated only 0.1233 mg As kg^{-1} FW which is still lesser than the critical level of arsenic contamination (0.15 mg kg^{-1} FW), So, potato growers can cultivate potato up to 20 mg kg^{-1} Arsenic contaminated soil using 20 g rice husk kg^{-1} soil. Since Arsenic content in tuber reduced with increasing the rice husk levels, so further on- farm research trial at arsenic contaminated areas is to be done to find out another bio-adsorbents to minimize more than 80% of Arsenic load from Potato tuber.

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