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Arsenic acquisition pattern in different plant parts of aromatic rice cultivars

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ABSTRACT

A field trial was conducted in Gontra village under Chakdaha block of Nadia district, West Bengal during rainy (*kharif*) season of 2020 to assess arsenic (As) accumulation in different plant parts of aromatic rice cultivars. The field trial was laid out in Randomized Block Design (RBD) with 15 treatments (aromatic rice cultivars) and three replications. Results revealed that the aromatic rice cultivar 'Poreiton' (collected from Manipur) showed maximum arsenic accumulation in grain (0.93 mg/kg) and husk (1.68 mg/kg); being statistically at par with cultivars 'Wairi-Chakhao' (0.87 and 1.55 mg/kg grain and husk, respectively) and ''Lalbadshabhog' (0.74 and 1.52 mg/kg grain and husk, respectively). Least arsenic accumulation was found in the cultivar 'Tulaipanji' (0.17 and 0.71 mg/kg grain and husk, respectively). Hence, the cultivar 'Tulaipanji' grain was found to be safe for human consumption, as the grain As content within the safe limit as per WHO's guideline (maximum 0.2 mg/kg of white rice). But other cultivars need some mitigation strategies with respect to water and nutrient management so that grain As content is kept within the safe limit.

Introduction

Rice is a staple food for more than 70% of global population and is produced in about 120 countries worldwide. India is the second-largest producer, with a total production of 177.64 million tonnes in 2019 (Banerjee *et al.,* 2022).West Bengal, the rice bowl of the country, is the richest reservoir of rice bio-diversity (Banerjee *et al.,* 2018).Aromatic rice (basmati type and non-basmati type) occupies a unique position among rice varieties on account of its excellent quality characters and thereby having a great potential in its export. This group of rice is popular and highly priced because of its aroma and cooking characteristics. The rice has its uniqueness in the fact that it releases aroma both on the field (during flowering and harvesting,) and off the field (during, milling, storing and cooking) (Heisnam *et al*., 2020). Many aromatic varieties are grown in restricted areas of West Bengal and hence, there is need to promote its cultivation in non-traditional areas also. Now-a-days, people give more interest on quality of the food rather than quantity. However, due to the presence of some contaminant like heavy metals, its quality has decreased by tenth fold and this might have great impact on its export potentiality. Arsenic is a metalloid that is found in the environment through natural events like volcanic eruption, weathering of rocks etc. and anthropogenic activities like mining, application

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pesticides etc. This heavy metal enters into human body and plant system through consumption of contaminated drinking and irrigation water respectively (Moulick *et al*.,2021). In July 2014, the World Health Organization set worldwide guidelines for safe levels of arsenic in rice, maximum being 0.2 mg/kg for white rice and 0.4 mg/kg for brown rice (Sohn, 2014). So, the present experiment was conducted to find out arsenic acquisition pattern of various aromatic rice cultivars in vegetative (root, stalk and husk) and economic part (grain).

Material and Methods

The field trial was laid out in Gontra village under Chakdaha block of Nadia district, West Bengal during *kharif* season of 2020. The experiment was laid out in Randomized Block Design (RBD) with 15 treatments (T_1-Poreiton, T_2-Chakhao-amubi, T_3-NC365, T_4-Tulaipanji, T_5-Wairi-chakhao, T_6-Lalbadshabhog, T_7-Kaminibhog, T_8-Gopalbhog, T_9-Monibhog, T_{10}-Radhunipagol, T_{11}-Kataribhog, T_{12}-Radhatilak, T_{13}-Kalonunia, T_{14}-NC324 and T_{15}-Gobindobhog) and three replications. These 15 aromatic cultivars were collected from different parts of Manipur and West Bengal. The seedlings were raised in separate plots and 28 days old seedlings were used for transplanting in the main field. Standard agronomic management practices were followed in the main field with recommended fertilizer dose of 40-20-20 kg N-P-K/ha.After harvesting, plants were digested and arsenic content of the digested sample was measured by using ASS (Analyst 200) coupled with FIAS 400 (a hydride generator) (Sparks *et al*., 2006).The collected data were analyzed statistically by the analysis of variance (ANOVA) technique using the SPSS ver. 20 software. The significant difference between treatments means was tested at $p \leq 0.05$. Linear regression-enter method was intervened to establish the relationshipbetween As content in economic (grain) and vegetative (root, stalk and husk) parts. To predict the presence of auto-correlation in the residuals of such regression models, Durbin-Watson statistics were used (Ghasemi *et al.,*2010).Agglomerative Hierarchical Clustering was done using XLSTAT 2017.

Results and Discussion

Arsenic accumulation in different plant parts

Different chemical properties of soil were determined before initiation of the present study. Results revealed that the soil of the experimental site had pH 6.84, organic carbon 0.72, 218 kg/ha available nitrogen, 48 kg/ha available phosphorus, 178 kg/ha available potassium and available arsenic of 5.77 mg/kg. In West Bengal and Bangladesh, during the dry wintery season, As contaminated ground water is used for rice production (Duxbury and Pnaullah, 2007; Roberts *et al*., 2007) thereby increasing As content in agricultural soil (Ahmad and Bhattacharya, 2019). Moreover the capability to transfer heavy metals from soil to crop differs for different crops and ultimately affects their bioaccumulation pattern (Sekara *et al*., 2005) which is in conformity with the present findings. The results revealed that aromatic rice cultivar 'Lalbadshabhog' showed maximum arsenic accumulation in root (8.55 mg/ kg) and this was found to be statistically at par with the cultivars 'Poreiton' (8.39 mg /kg) and 'Wairi-Chakhao' (8.09 mg/ kg) collected from Manipur (Table 1). The least root As accumulation was recorded in 'Tulaipanji' (5.92mg/ kg). It was also observed that the maximum As content in stalk was found in 'Wairi-Chakhao' (3.35mg /kg); being statistically at par with stalk As content of the cultivars Poreiton; (3.20 mg /kg) and 'Lalbadshabhog' (3.08 mg /kg). While the least stalk As content was recorded in 'Gopalbhog' (2.11 mg/ kg). Greater arsenic content in husk was assessed in the cultivar 'Poreiton' (1.68 mg /kg); and it was statistically at par with husk As content of the cultivars 'Wairi-Chakhao' (1.55 mg /kg) and 'Lalbadshabhog' (1.52 mg /kg). However, the least As accumulation in husk was recorded with 'Tulaipanji' (0.71 mg /kg). From the results of the experiment, the accumulated arsenic followed the order root>stem>leaf>grain which was in conformity with the findings of Abedin *et al*., 2002. There was significant difference in grain As content of different tested aromatic rice cultivars which was in accordance with the findings of the Meharg and Rehman (2003) and Duxbury and Zavala (2005). The build up As in the paddy soil from continuous using of contaminated water eventually augmented the rice grain arsenic accumulation (Upadhyay *et al*., 2019).

Table 1: Arsenic content in different plant parts of tested aromatic rice cultivars grown during *kharif* 2020

Treatment	Arsenic content (mg /kg)			
	Root	Stalk	Husk	Grain
T_1-Poreiton	8.39	3.20	1.68	0.93
T_2-Chakhao-amubi	7.22	2.45	0.94	0.28
T_3-NC 365	7.11	2.25	1.08	0.47
T_4-Tulaipanji	5.92	2.34	0.71	0.17
T_5-Wairi-chakhao	8.09	3.35	1.55	0.87
T_6-Lalbadshabhog	8.55	3.08	1.52	0.74
T_7-Kaminibhog	7.48	2.16	1.01	0.39
T_8-Gopalbhog	7.57	2.11	0.97	0.54
T_9-Monibhog	6.84	2.57	1.10	0.23
T_{10}-Radhunipagol	6.76	2.30	0.93	0.21
T_{11}-Kataribhog	6.49	2.61	0.91	0.25
T_{12}-Radhatilak	7.15	2.20	0.97	0.61
T_{13}-Kalonunia	7.19	2.50	0.92	0.47
T_{14}-NC 324	6.45	3.05	0.94	0.23
T_{15}-Gobindobhog	6.23	2.79	0.91	0.21
S.Em±	0.37	0.21	0.14	0.05
CD (P=0.05)	0.75	0.43	0.28	0.11

Table 2: Relationship between As content in economic (grain) and vegetative (root, stalk and husk) parts of tested rice cultivars

Relationship	R^2	Adj. R^2	SE_{est}	Durbin-Watson
Grain Arsenic = 0.178root arsenic** -.0.027stalk arsenic + 0.387husk arsenic-1.181	0.835	0.791	0.115	1.724

***Significant at $p_{0.05}$ and **Significant at $p_{0.01}$**

Table 3: Class statistics of Agglomerative Hierarchical Clustering (AHC) along with cluster-wise mean values of As accumulation of different plant parts

Cluster	Size	Member of cluster	Mean As content (mg /kg)± SD			
			Grain	Root	Stalk	Husk
1	3	Poreiton, Wairi-Chakhao and Lalbadshabhog	0.85 ± 0.0971	8.34 ± 0.2335	3.21 ± 0.1353	1.58 ± 0.0850
2	12	Chakhao-Amubi, NC-365, Tulaipanji, Kaminibhog, Gopalbhog, Monibhog, Radhunipagol, Kataribhog, Radhatilak, Kalonunia, NC-324 and Gobindobhog	0.34 ± 0.1501	6.87 ± 0.5107	2.44 ± 0.2787	0.95 ± 0.0982

SD=standard deviation

The highest grain As content was recorded for the cultivar 'Poreiton' (0.93 mg /kg); being statistically at par with cultivar 'Wairi-Chakhao'. In contrary to that, the least grain As accumulation was found in the cultivar 'Tulaipanji' (0.17mg /kg) and the amount of As is very much within the safe limit of human consumption (≤ 2 mg /kg). Multiple linear regression analysis of grain As content as a dependent variable showed that root As content and husk As content had positive significant and non-significant relationship with grain As content, respectively (Table 2). Therefore, contribution of root As content could only bring significant increase in grain As content. While grain As content had a synchrony with husk As content, but not in a significant way.

Hierarchical clustering

Agglomerative Hierarchical Clustering (AHC) was performed for clustering the different homogeneous groups of aromatic rice cultivars on the basis of As accumulation in different plant parts (Banerjee *et* *al*., 2018). Based on AHC analysis, a dendrogram is illustrated in Figure 1 which reveals that 15 different types of rice cultivar (aromatic) were grouped into two clusters - Cluster I included three cultivars (Poreiton, Wairi-Chakhao and Lalbadshabhog) and Cluster II was comprised of twelve cultivars (Chakhao-Amubi, NC-365, Tulaipanji, Kaminibhog, Gopalbhog, Monibhog, Radhunipagol, Kataribhog, Radhatilak, Kalonunia, NC-324 and Gobindobhog). The class and descriptive statistics of different rice cultivar obtained from AHC analysis has been presented in Table 3. Based on the results of Agglomerative Hierarchical Clustering (AHC) of tested rice cultivars, it can be concluded that three rice cultivars under Cluster I namely Poreiton, Wairi-Chakhao and Lalbadshabhog showed greater tendency of As accumulation in different plant parts than other tested cultivars. Contrarily, twelve cultivars (Chakhao-Amubi NC-365, Tulaipanji, Kaminibhog, Gopalbhog, Monibhog, Radhunipagol, Kataribhog, Radhatilak, Kalonunia, NC-324 and Gobindobhog) had lower As accumulation in different plant parts. Moreover, the least As acquisition was exhibited by 'Tulaipanji'.

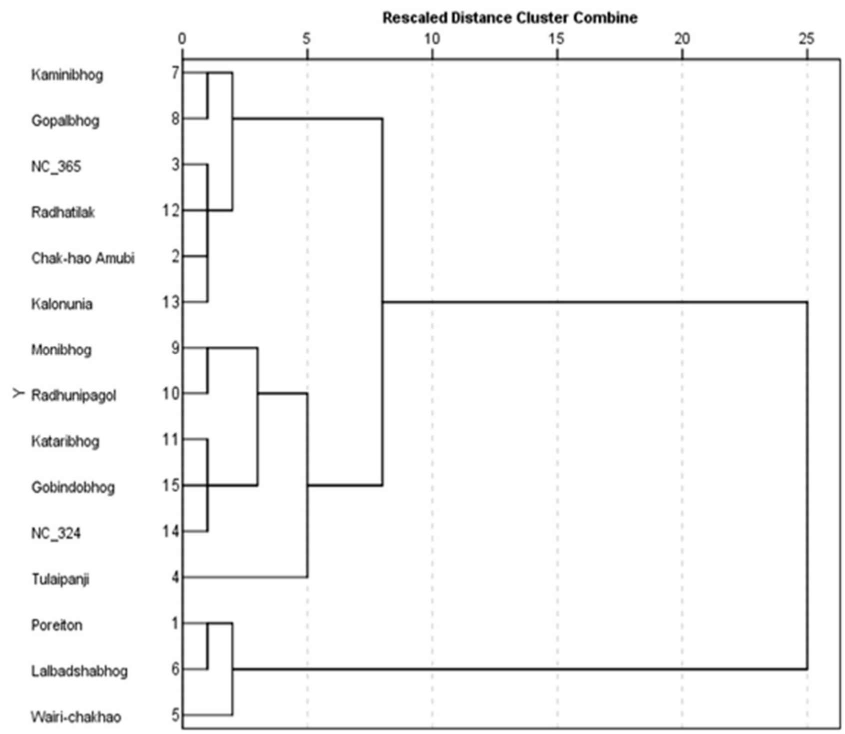

Figure 1: Clustering of tested aromatic rice cultivars based on their As acquisition pattern in different plant parts by agglomerative Hierarchical clustering using Euclidean dissimilarity distance

Conclusion

Based on the above findings, it is concluded that grains of 'Tulaipanji' was found to be safe for consumption. However, the cultivars 'Radhunipagol' and 'Gobindobhog' were found to produce grains with threshold limit of As. So they can be consumed as it is by taking up some remedial measures while cooking or processing. But other cultivars need some mitigation strategies in crop cultivation with respect to water and nutrient management so that grain As acquisition is kept within the safe limit. It further concluded that the people living in the arsenic affected area need to be taken into account the differences between rice types and cultivars in assessing the dietary intake of arsenic.

Conflict of interest

The authors declare that they have no conflict of interest.

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