Management Strategies to Reduce Arsenic Uptake by Rice

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Abstract

Arsenic contaminated irrigation water in Bangladesh is most likely responsible for high arsenic levels in soils used for growing rice. Elevated arsenic concentrations in rice grain produced in such high arsenic water-soil environments have been demonstrated. Because Bangladeshi diets are dominated by rice, arsenic contaminated rice could be aggravating existing human health risks from arsenic contaminated drinking water in southern and central Bangladesh.

Recently several surveys of arsenic in rice grain (788 samples total) have been undertaken (Shah et al., 2004; USAID, 2003; Duxbury et al., 2003; Hironaka & Ahmad, 2003, Meharg & Rahman, 2003). Utilizing the distribution of these grain arsenic concentrations and per capita daily consumption of rice (450 g), we estimate that daily arsenic intakes from 24% of the rice samples would be in excess of daily water intakes at the current Bangladeshi standard of 50 ppb. Alternatively, daily arsenic intakes from 84% of the Bangladeshi rice samples would exceed daily arsenic intakes from water at the US and European drinking water standard of 10 ppb. These simplified estimates of arsenic consumption from only rice and water indicate that arsenic from rice is an important source of exposure in the Bangladeshi food system. Thus management strategies need to be developed to reduce arsenic uptake by rice.

Reduction of arsenic uptake by rice can be addressed by avoidance or minimization strategies. One avoidance approach can be derived from the spatial analysis work of Ross et al. (2005). Their study identified that 24% of total irrigated boro rice in Bangladesh is grown in areas where groundwater arsenic is greater than the 50 $\mu g\ L^{-1}$ Bangladesh standard. Many of the areas with high groundwater arsenic (100-200 $\mu g\ L^{-1}$; > 200 $\mu g\ L^{-1}$) are found in the central part of the country near the Padma and Meghna rivers with ample surface water. Development of more irrigation schemes with these surface water sources could provide a clean substitute for contaminated groundwater and avoid further degradation of soils in these areas.

Reduction of iron oxides under flooded, anaerobic conditions releases inorganic arsenic from soils/sediments which is then more available for uptake by rice. Under aerobic soil conditions, most arsenic remains bound to iron oxides and unavailable to plants. So for irrigated boro rice areas with high arsenic groundwater and no uncontaminated surface water substitute, avoidance options might include shifting to upland (nonflooded) cereal crops such as wheat or maize. Upcoming data from the USAID Arsenic Project nation-wide survey will be used to make comparisons of arsenic contents in maize or wheat relative to boro rice in Bangladesh.

Minimization management strategies to reduce arsenic accumulation in rice include varietal selection and more aerobic cultivation practices. Limited studies comparing arsenic uptake in Bangladeshi rice varieties points to significant genetic and site variation (Table 1), but more comparative studies of genotype x environment (G x E) interactions with existing varieties are

needed. Also plant breeding programs need to seek traits that both increase tolerance to arsenic and reduce arsenic uptake. The recent work of Liu and colleagues (2004, 2005) is an important contribution to this area. They demonstrated that differences in arsenic uptake between rice varieties are influenced by iron plaque formation and regulated by plant phosphorus status.

Table 1

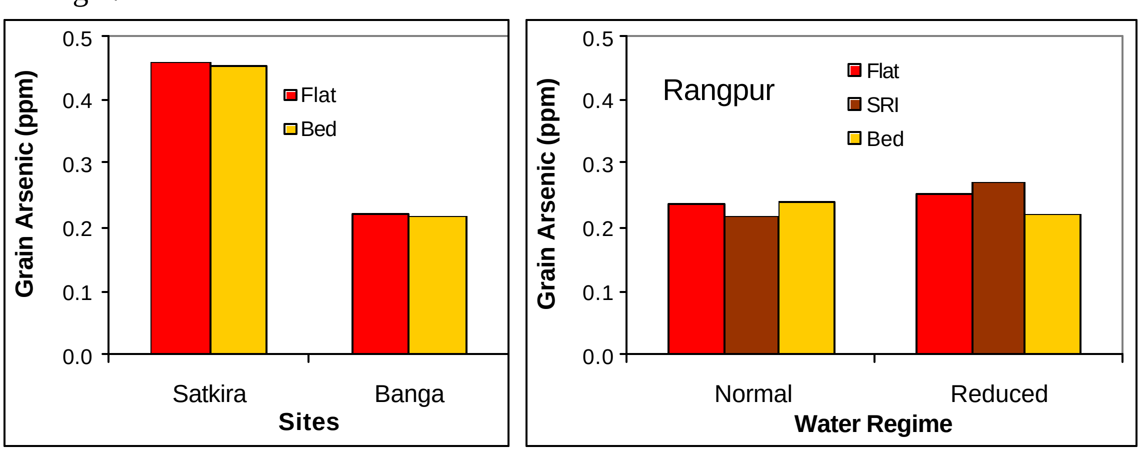
Bangladesh Varieties	Dinajpur[1]	Gazipur[2]	Brahmanbaria[3]
	Grain arsenic ((µg/g)		
BR11	0.104	0.043	-
BR28	-	0.067	0.550
BR29	-	0.180	0.576
BR32	0.173	0.044	-
BR33	0.378	0.206	-
BR 36	-	-	0.527
BR39	0.196	-	-
BINA 6	-	-	0.591

[1] Soil Management CRSP, unpublished
[2] Meharg and Rahman, 2003
[3] USAID, 2004

For the reasons stated above, uptake of arsenic by rice is reduced when the growing environment is more aerobic. Permanent raised beds, SRI (System of Rice Intensification) and aerobic rice are emerging cultivation practices that produce rice in a more aerobic soil environment by avoiding flooding and using less irrigation water. So far experiment station and farmer participatory trials with permanent raised beds and SRI show promise, while aerobic rice is still a new, developing technology.

Despite our expectations that aerobic cultivation practices would reduce arsenic uptake by rice, results from experiments with permanent raised beds and SRI have not shown differences in arsenic concentration to date (Fig 1). Nevertheless, on a highly contaminated soil (68 mg/kg) Xie and Huang (1998) observed a 22% increase in yield and a 24 % decrease in rice grain arsenic after furrow drainage and maintenance of moist soil.

Fig 1.



Opportunities for remediation of arsenic contaminated flooded soils by amendments are limited because most proposed additions such as ferrous sulfate would have negative secondary effects in flooded soils (iron toxicity). Xie and Huang (1998) found that MnO_2 addition effectively reduced As (III) in the soil solution, but only slightly changed the arsenic concentration in rice grain. Under aerobic soil conditions and with a very contaminated soil, Lombi et al. (2004) reported that gypsum additions reduced extractable arsenic and arsenic in the soil pore water. Arsenic uptake by lettuce was decreased with the gypsum treatment but not in ryegrass. The use of gypsum and MnO_2 as amendments for flooded rice in Bangladesh should be investigated further.

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