

Original Research Article

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Mitigate Grain Arsenic Load of *Summer* Rice through Water Management

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ABSTRACT

High yield potentiality of summer rice motivates farmers in West Bengal to grow rice even in summer season. Summer rice receives few fold higher irrigation over other aerable crops. Farmers of this area irrigate 1300-1400 mm water for *summer* rice. In Nadia district of West-Bengal during summer season, the main source of irrigation water is ground water which contains high amount (0.098-0.345 mgL⁻¹) of arsenic which is responsible for higher arsenic concentration in grain and straw. A field experiment was carried out during February to May, 2014 with six irrigation regimes. The irrigation regimes were I₁- Continuous ponding, I₂- Intermittent ponding, where irrigation was given two days after disappearance of ponded water, I₃- Intermittent ponding, irrigation was given four days after disappearance of ponded water, I₄- Saturation with SRI transplanting, I₅- Intermittent ponding, irrigation was given two days after disappearance of ponded water, I₆- Raised and sunken bed in a ratio of 1:2. Soil water stress in I₂ and I₄ were imposed during 15 to 40 days after transplanting. However, in case of I₅ stress imposition stage was 65 to 80 DAT. Rest period for I₂, I₃, I₄ and I₅ regime field was kept under continuous ponding situation. Results showed that the grain (0.52 mgkg⁻¹) and straw (3.05 mgkg⁻¹) arsenic content were significantly less in I₄ where (36.4%) less water was irrigate over I₁. No significant yield reduction was found under I₄ (6.47 Mg ha⁻¹) as compare to I₁ (6.64 Mg ha⁻¹). Application of 100 mm and 380 mm less water respectively under I₅ and I₆ showed decrease in grain arsenic content by 36.7% and 26.6% respectively. Raise and sunken bed can effectively decrease grain arsenic content. But all three regimes significantly decrease grain yield. To reduce arsenic content in rice grain and straw without affecting yield, the field should be kept saturated during 15-40 days after transplanting.

Keywords

Rice, Irrigation regimes, Arsenic

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Introduction

Rice is a staple food in South East Asia. Worldwide, about 79 million ha of irrigated lowlands provide 75% of the total world's rice production (Maclean *et al.*, 2002). Higher grain yield and monetary return motivates the

farmers of Bengal delta to grow rice in dry (January to May) season popularly known as summer rice. At the field level, rice receives up to two to three folds more water than other irrigated crops (Tuong *et al.*, 2005). Cultivate one hectare of rice in summer season on an average, 1200 to 1300 cubic meter of water is

required. On an average, 34-43% of the world irrigation water is used to irrigate rice (Bouman *et al.*, 2006). Besides, water is becoming increasingly scarce and grave concerns exist about the sustainability of irrigated agriculture (Rijsberman, 2006). In West Bengal, in spite of ground water depletion, farmers are growing *boro* rice covering more than 1.4 mha. Not only the scarcity of ground water but also arsenic concentration in remaining ground water of the vast area is above the critical level as determined by WHO (0.05mg/l). This high concentration of arsenic present in ground water causes cancer and other severe diseases, which is threatening to human health. It is suspected that the STW irrigation water may also have a high As content which may increase the As level in the soils, and thus, high amounts of As may accumulate in food grains creating an additional health hazard.

Rapid adsorption of As from irrigation water to soil may explain the spatial patterns found in irrigation canals and some paddy fields (Farid *et al.*, 2005). When the amount of arsenic in the groundwater is high, it has been observed that the levels of arsenic in agricultural land soil and plants are correspondingly high (Roychowdhury *et al.*, 2008). High As concentrations in irrigation-water can lead to elevated concentrations of As in soil and subsequently in rice grain and straw (Duxbury *et al.*, 2003; Williams *et al.*, 2006). Very high levels of Arsenic accumulation in rice straw indicates that consumption of such contaminated straw by cattle which could be a direct threat for their health and also, indirectly, to human via presumably contaminated bovine meat and milk (Abedin *et al.*, 2002). To decrease the rice grain and straw arsenic load it is an important target to reduce potential water use (Wang *et al.*, 2002). Water saving irrigation technology based on the concept of alternate wetting and drying have been shown to save

water (Bouman and Tuong, 2001; Belder *et al.*, 2004). Another one of the major water saving technology developing is continuous soil saturation (Borell *et al.*, 1997). Deficiency of water during vegetative stage shows insignificant effect on grain yield (Yambo and Ingram, 1988). A farmer's field study was conducted to (i) find out the level of arsenic accumulation by rice grain and straw with irrigation water contaminated with arsenic and (ii) to mitigate grain arsenic content through water management without affecting yield.

Materials and Methods

Selection of study area

The experiment was conducted at Ghentugachi village of Nadia district in West Bengal, India (23°02' N, longitude 88°35' E; altitude of 8.8 m amsl) during summer season 2014. The soil type of experimental field was silty loam with pH value of 7.22. The basic properties of the soil are presented in Table 1.

Details about experiment

Six irrigation management treatments were tested in randomized block design (RBD) with four replications. The treatments consisted of T₁- Continuous ponding (spacing 15 ×15 cm), T₂- Intermittent ponding 15- 40 DAT, 2 days after disappearance (spacing 15 ×15 cm), T₃- Intermittent ponding 15- 40 DAT, 4 days after disappearance (spacing 15 ×15 cm), T₄- Continuous soil saturation (SRI, spacing 20 ×20 cm), T₅- Intermittent ponding 15- 40 DAT, 2 days after disappearance (spacing 15 ×15 cm) and 65 DAT to last irrigation, T₆- Raised and sunken bed in a ratio of 1:2. The plot size was 9 m × 5 m. Thirty eight days old Shatabdi (IET 4786) rice seedling was sown on 04/02/2011 (6th standard week). Total fertilizers were applied at a rate of 100 kg N ha⁻¹, 60 kg P₂O₅ ha⁻¹ and 60 kg K₂O ha⁻¹. The crop was harvested on 05/05/2014.

Statistical analysis

Differences among irrigation regimes on rice yield (grain and straw) were tested with Fisher's least significant difference ($P \leq 0.05$) test using analysis of variance as mentioned in Panse and Sukhatme (1967). The statistical measurements of coefficient of determination (R^2) of the equations were calculated to assess the degree of association between two variables.

Calculations

The depth of irrigation for intermittent ponding was calculated by following the relationship proposed by Chaudhary (1997):

$$D_i = (\Theta_s - \Theta_i) D_r + D_s$$

Where D_i is the depth of irrigation water to be applied (mm); D_r is the depth of root zone (mm); D_s is the depth of submergence required (mm) in the present study D_s value was 50 mm; Θ_s is the average volumetric moisture content (m^3m^{-3}) of the root zone at saturation and Θ_i is the average volumetric soil water content (m^3m^{-3}) at the time of irrigation water application. Both Θ_s and Θ_i are expressed as fractions. The term $(\Theta_s - \Theta_i)$ gives the volume of water required to raise the water content of a unit volume of soil to saturation.

Analysis of arsenic

Total arsenic

Total arsenic was analyzed in all samples by wet ashing procedure in hot plate using tri-acid mixture of nitric acid perchloric acid and sulphuric acid at 10:4:1 ratio following the method modified by Datta *et al.*, (2010) and Datta *et al.*, (2011) and properly digested sample were diluted with Millipore water, passed through filter paper and made the volume 10 ml with concentrated hydrochloric acid (5ml) was added to it and shaken well

then 1 ml mixture of potassium iodide (5%) and ascorbic acid (5%) mixture was added and kept the aliquot for 45 min for transformation of arsenate to arsenite (Haring *et al.*, 1982). Final volume was made up to 50 ml with Millipore water for reading in atomic absorption spectrophotometer (FI-HG-AAS, Perkin Elmer Analyst 400) using external calibration through arsenic as standard. For each sample three replicates were taken and the mean values were obtained on the basis of calculation of those three replicates.

Results and Discussion

The highest amount of irrigation water applied in I_1 (1100 mm) showed highest amount of arsenic in soil (15.7 mg kg^{-1}), straw (3.63 mg kg^{-1}) as well as grain (0.79 mg kg^{-1}). On the other hand, in I_4 , where least amount of irrigation water applied (700 mm) found least concentration of soil arsenic (14.6 mg kg^{-1}). The rice grain arsenic content found lowest in I_5 (0.5 mg kg^{-1}) with the grain yield (6.54 t ha^{-1}) produced is at par with I_1 (6.64 t ha^{-1}).

Through water management the grain arsenic concentration in continuous soil saturation can be reduced upto 34.2% in Shatabdi (IET 4786) rice variety with the saving of water is around 36.4% and there is no significant yield difference.

After harvesting of the rice crop in case of continuous soil saturation the soil arsenic content increase at rate of 3.55% but in case of continuous ponding the increase rate is 11.35%.

Arsenic concentrations in rice roots, straw and grain increased significantly ($P < 0.001$) with increasing arsenic content in irrigation water. Regardless of irrigation water arsenic concentration, rice tissue arsenic concentration followed the trend: root > straw > grain (Fig. 1 and 2; Table 2).

Fig.1 The relationship between the amounts of arsenic accumulated by rice grain and straw and arsenic added through irrigation water

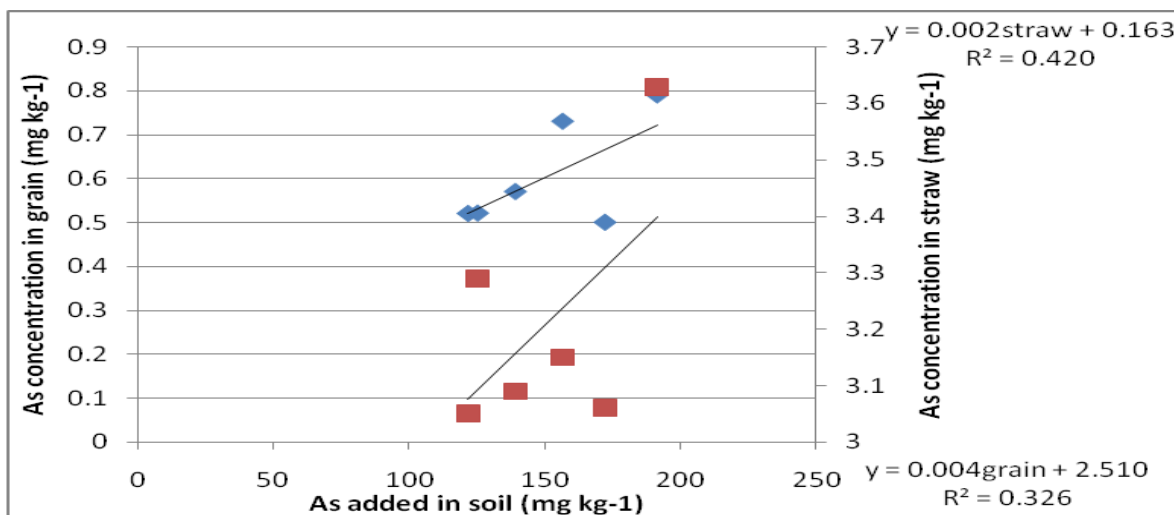


Fig.2 Relationship between soil arsenic and arsenic content in rice grain

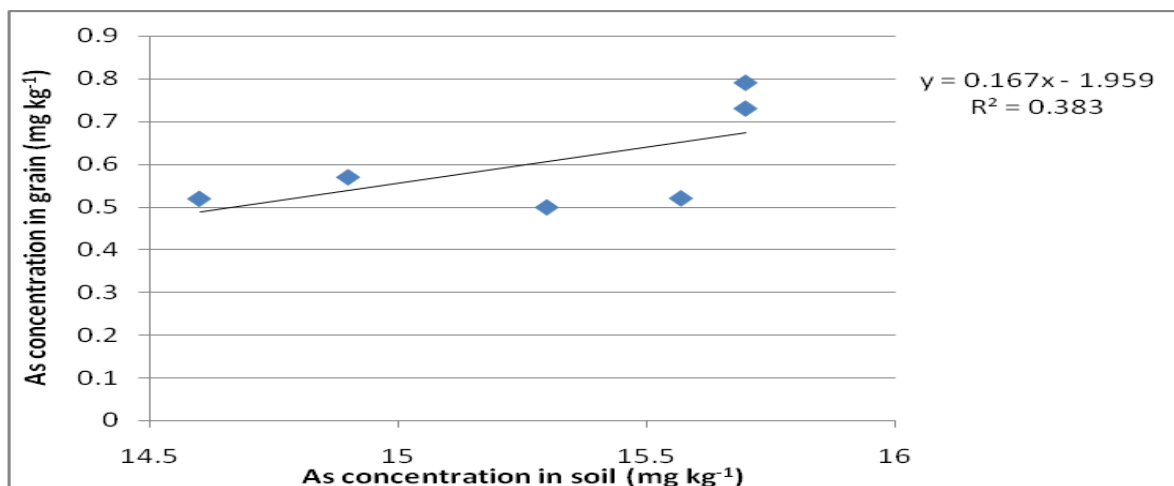


Table.1 Important physicochemical properties of the experimental soil

Physicochemical properties	Value
Sand	41.8
Silt	41.5
Clay	16.7
pH	7.22
Electrical conductivity	1.18 ds m ⁻¹
Organic carbon	9.90 g kg ⁻¹
Available nitrogen	152.52 kg ha ⁻¹
Available phosphorus	65.7 kg ha ⁻¹
Available potassium	135.5 kg ha ⁻¹

Table.2 Effect of irrigation regimes on arsenic concentration of rice grain and straw with rice grain and straw yield

Irrigation Regime	Water irrigated (mm)	As added, mg m ⁻² soil through irrigation water	As concentration (mg kg ⁻¹)			Grain yield, Mg ha ⁻¹	Straw yield, Mg ha ⁻¹
			soil	grain	straw		
I ₁	1100	191.4	15.70	0.79	3.63	6.64	9.05
I ₂	900	156.6	15.70	0.73	3.15	6.52	9.14
I ₃	800	139.2	14.90	0.57	3.09	5.74	8.55
I ₄	700	121.8	14.60	0.52	3.05	6.50	10.30
I ₅	1000	172.2	15.30	0.5	3.06	6.54	9.21
I ₆	720	125.3	15.57	0.521	3.29	6.25	8.06
LSD (p = 0.05)		37.6	0.82	0.075	0.18	0.165	0.32

Imposition of saturation during vegetative stage caused insignificant changes in grain yield with significant reduction in arsenic concentration in rice grain

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