Deficit Irrigation an option to mitigate Arsenic load in Rice Grain

Biswaji Basu[A], Champak Kumar Kundu[B], **Supradip Sarkar**[C] and Saroj Kumar Sanyal[D]

[A]Department of Agronomy, BCKV, Mohanpur, India, 741252, Email: dearbiswajit@gmail.com
[B]Department of Agronomy, BCKV, Mohanpur, India, 741252, Email: champakbckv@gmail.com
[C]DEpartment of Agric. Meteorology and Physics, BCKV, Mohanpur, 741252, India, Email: sdip2006@gmail.com
[D]Arsenic Research Laboratory, BCKV, Kalyani, 741235, India, Email: sarojsanyal@yahoo.co.in

Abstract
Field trial was carried out during 2008 to assess impact of irrigation on arsenic status of soil, leaf and grain of rice and water use efficiency of the crop. Four levels of irrigation i) continuous ponding (CP); ii) intermittent ponding (IP); iii) saturation and iv) aerobic were imposed to the crop during 15 to 45 days after transplanting (DAT). Rest of the period, irrespective of regimes crop was exposed to CP. Highest grain yield recorded under IP. Arsenic load in soil, leaf and grain attained highest value under CP and decreased in the order of IP>Saturated>Aerobic regimes. Impact of irrigation regimes on variation in total arsenic load was maximum in soil (80.5%) followed by leaf (40%) and grain (18%). Arsenic added to the rice field through contaminated water poses strong relationship with total arsenic status of soil, leaf and grain. Water use efficiency attained highest value under aerobic regime and closely followed by IP.

Introduction
Rice-rice is the main cropping sequence of Bengal delta, which covers one state (West Bengal) of India and major part of Bangladesh. Notably higher (55 – 80%) grain yield over the rainy season rice motivate the farmers to cultivate rice (summer rice) in post winter season (February to March) under irrigated condition. Farmers irrigate 1200 to 1400 mm water to meet up the higher (3-5.5 mm/day) evapotranspiration demand during its growing period and 70% of this meets up by ground water. Arsenic is a known carcinogen and as per World Health Organization (WHO) it is highly toxic to human health when its concentration in water goes above 50 μg /l. At present ground water arsenic concentration of 2/3rd land area of Bangladesh and 1/3rd land area of West Bengal is reported above the WHO critical level. This contamination puts at least 100 million people at risk of cancer and other arsenic related diseases. Irrigate rice with polluted water resulted in increase of arsenic status in different parts of the crop (Meharg 2004). Thus million of people who are living out side the arsenic contaminated area also consume the toxic arsenic every day by eating rice grown in the contaminated area. Besides, amount of fresh water and share of irrigation in it, is showing a declining trend against time. In contrast lowest (20 – 30 kg/ha/mm) value of water productivity has been reported for rice (Zwart and Bastiaanssen 2004). Curtail in amount of irrigation water at stress allowable stage of the crop can enhance crop water productivity without notable decrease in yield (Sarkar 2001). Considering these a farmer's field study was planned to assess the role of different levels of deficit irrigation on reduction of arsenic load in rice grain and improve its water productivity.

Methods
The experiment was conducted on farmers field located (23^{0}02' N, longitude 88^{0}35' E; altitude of 8.8 m amsl) in an arsenic affected village of West Bengal, India during 2008.The soil of the field was of silty loam type (Aeric Haplaquept). Four levels of irrigation were: i) Continuous ponding (CP), followed by the farmers of the locality and was the control treatment; ii) Intermittent ponding (IP) irrigation was given when soil matric potential (Ψ_m) at 20 cm depth reaches to – 0.02 M Pa after disappearance of ponded water; iii) Saturation where 0 to 50 cm soil profile was maintained at saturation state and iv) Aerobic where irrigation was given when Ψ_m at 50 cm depth reaches to – 0.05 M Pa to recharge 0 to 50cm soil at field capacity ((Ψ_m = - 0.03M Pa) level. Treatment ii, iii and iv were imposed during 15 to 45 DAT. There after till 80 DAT under all the regimes crop was exposed to CP. Depth of irrigation under CP was 4±1 cm. The experiment was laid out in a randomized block design with three replications. Rice variety Gontera Selection 3 was taken as the test crop. Last irrigation was given on 80 DAT. Water, plant and soil samples were digested with tri acid mixture, filtered and processed for estimation of total arsenic by using an atomic absorption spectrophotometer (Perkin-Elmer make, model: Analyst – 200) coupled with FIAS-400 hydride generator.

Calculations
The depth of irrigation for IP was calculated by the equation proposed by Chaudhary (1997) as:

$$D_i = (\theta_s - \theta_i)\, D_r + D_s \qquad (1)$$

Where, D_i is, depth of irrigation (mm); D_r is, depth of root zone (mm); D_s is, depth of submergence (mm) in this study D_s was 50 mm; θ_s is the average volumetric moisture content (AVMC, $m^3 m^{-3}$) of the root zone at saturation and θ_i is the AVMC ($m^3 m^{-3}$) at the time of irrigation. The term (θ_s - θ_i) gives the volume of water required to raise the water content of a unit volume of soil to saturation.

Results

Imposition of deficit irrigation during 15 to 45 DAT decreased the amount of arsenic added to rice field over CP by 40 to 130% and 19 to 62% respectively at 45 DAT and at harvest (Table 1). Under all the regimes adoption of a common irrigation level (CP) from 46 to 80 DAT was responsible for the reduction in variation of arsenic at harvest over 45 DAT. Irrespective of the study period total arsenic status in soil, leaf and grain attained highest value under CP and decreased in the order of IP>Saturated>Aerobic. On 45 DAT, under different regimes variation in total arsenic status of soil and leaf was 81 and 45% respectively. At harvest the same for soil and leaf reduced to 80 and 35%. In case of rice grain the variation was 18%. Amount of arsenic added to rice ecosystem through contaminated water shows strong relationship with total arsenic status of the soil and rice leaf (Figure 1 and 2).The relationship was stronger with soil than that of the leaf. Impact of irrigation on total arsenic status of soil and leaf was more prominent at 45DAT than at harvest. Grain yield also possess a good relationship with arsenic added through contaminated water (Figure 3). Arsenic added through irrigation showed strongest relationship (R^2 = 0.94) against soil arsenic status. Data presented in table 1 and the R^2 value of figure 4 revealed that study site soil act as a good sink on arresting the amount of arsenic added to the soil and reduces the transport of arsenic to rice grain.

Difference in amount of water irrigated under four regimes significantly varied the grain yield (Table 2). Under IP regime application of 200 mm less water increased grain yield by 4%. This results support the hypothesis of negative impact of arsenic on grain yield of rice. Exposes of a water loving crop like rice to higher degree of water stress (Saturated and aerobic regimes) have negative impact on various physiological processes, which was well reflected in grain yield status. Present study shows that plant can recover the moderate degree of water stress (IP) if it imposed at the stress allowable stage. Water use efficiency (WUE) attained the highest value under aerobic regime followed by IP. Magnitude of WUE decreased by 5.11, 10.78 and 36.56% respectively under IP, saturated and CP regimes over aerobic condition.

Conclusions

Considering degree of arsenic pollution, yield and water use efficiency as well as easiness in operation intermittent ponding can be adopted by the farmers of the arsenic contaminated area in place of continuous ponding. Soil acts as a good sink in arresting arsenic towards it transport to rice leaf and grain.

Table 1. Effect of irrigation levels on total arsenic status of soil and plant parts at different crop stages

Irrigation levels	At 45 Days after transplanting			At harvest			
	Arsenic added, mg/m^2 soil	Total arsenic, mg/kg		Arsenic added, mg/m^2 soil	Total arsenic, mg/kg		
		Soil	Leaf		Soil	Leaf	Grain
CP	0.11	34.05	12.34	0.20	44.34	19.49	0.98
IP	0.08	28.85	10.28	0.16	40.40	18.29	0.93
Saturated	0.06	23.06	9.79	0.14	27.62	16.35	0.90
Aerobic	0.05	18.75	8.51	0.12	24.61	14.38	0.83

Table 2.Amount of water irrigated, grain yield (GY) and water use efficiency (WUE) under varying levels of irrigation

Irrigation levels	Water irrigated, mm				GY, t/ha	WUE, kg/ha/mm
	0-15 DAT	16-45 DAT	45-80 DAT	Total		
CP	170	520	510	1200	4.33	3.61
IP	170	320	510	1000	4.69	4.69
SAT	170	200	510	880	3.92	4.45
ARB	170	130	510	740	3.65	4.93
LSD (P=0.05)					0.33	

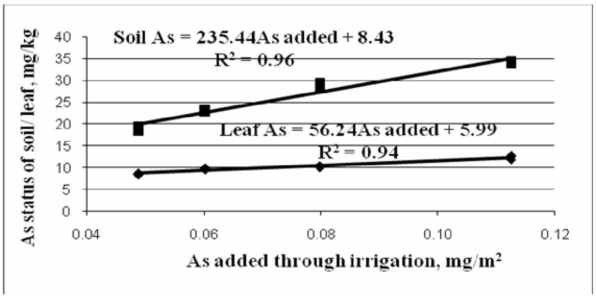

Figure1. Relationship between arsenic added through irrigation with total arsenic status of soil and rice leaf at 45 days after transplanting.

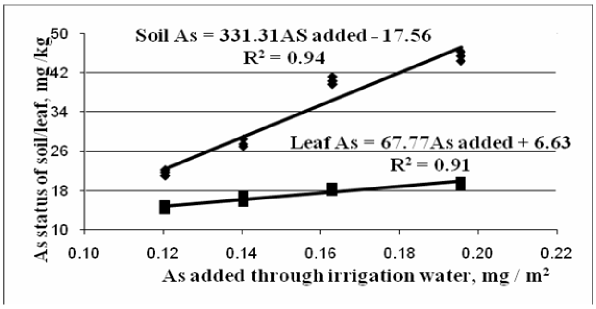

Figure2. Relationship between arsenic added through irrigation with total arsenic status of soil and rice leaf at harvest.

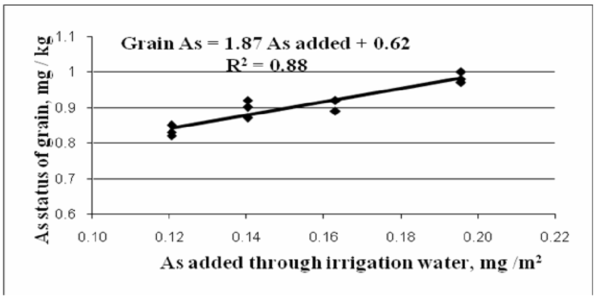

Figure 3. Relationship between arsenic added through irrigation with total arsenic status of grain.

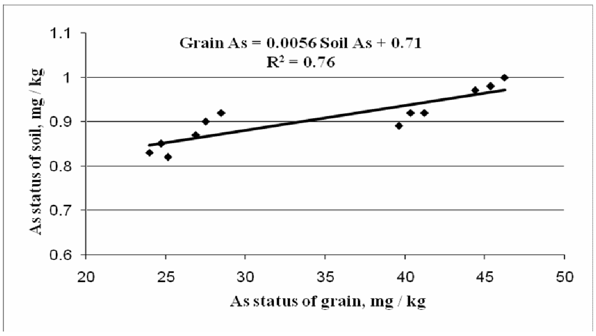

Figure 4. Relationship between total arsenic status of soil with total arsenic status of grain.

References

Chaudhary TN (1997) Water management for rice for efficient production. Bulletin. Directorate of Water Management Research, Patna, India, 63 p.

Meharg AA (2004) Arsenic in rice – understanding a new disaster for South-East Asia. *Trends in Plant Science*. **9**, 415 – 417.

Sarkar S (2001) Effect of water stress on growth, productivity and water expense efficiency of summer rice. *The Indian J. of Agric. Sci*. **71**, 153 –158.

Zwart SJ, Bastiaanssen WGM (2004) Review of measured crop water productivity values for irrigated wheat, rice, cotton and maize. *Agric. Water Manage.* **69**, 115 – 133.