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Arsenic Accumulation in Elephant Foot Yam (*Amorphophallus paeoniifolius* Dennst. Nicolson) in Deltaic West Bengal : Effect of Irrigation Sources and Nutrient Management

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Abstract

In India, Arsenic (As) toxicity problem is prevalent in the endemic areas of Ganges delta of West Bengal, especially, in irrigated crops. Elephant foot yam is a popular vegetable in this region and fits well into cropping systems under irrigated conditions. The present study was aimed to assess As contamination in the crop and to explore possibilities of reducing the accumulation through the use of harvested rain water along with nutrient management with greater emphasis on organic manures. Field experiments were conducted at Nonaghata-Uttarpara village, Haringhata block, Nadia district, during summer seasons of 2009 and 2010. The experiment was laid out in split plot design with two irrigation sources in main plots and four nutrient levels in sub plots, replicated thrice. Irrigation sources were shallow tube well (STW) and pond water (PW). Nutrient management options were recommended dose of fertilizers (RDF) (NPK @ 200:120:140 kg ha^{-1}) + FYM @ 10 t ha^{-1}, RDF + higher dose of P (double the dose of P) (NPK @ 200:240:140 kg ha^{-1}) + FYM @ 10 t ha^{-1}, 75% RDF (NPK @ 150:90:105 kg ha^{-1}) + FYM @ 10 t ha^{-1} and 75% RDF + higher dose of P (NPK @ 150:180:105 kg ha^{-1}) + FYM @10 t ha^{-1}. Results revealed that corm yield did not vary significantly between the irrigation sources, but As accumulation was higher under irrigation from shallow tube well. Application of 75% RDF + double the dose of P (NPK @ 150:180:105 kg ha^{-1}) + FYM @10 t ha^{-1} resulted in maximum yield with the least As accumulation.

Key words: Elephant foot yam, arsenic, irrigation, nutrient management

Introduction

Elephant foot yam [*Amorphophallus paeoniifolius* (Dennst.) Nicolson] is a tropical tuber crop having high production potential and popularity as a vegetable in various delicious cuisines. Many indigenous ayurvedic and unani medicinal preparations are also made using its tubers. The tubers are believed to have blood purifying characteristics and are used in medicines for the treatment of piles, asthma, dysentery and other abdominal disorders. In India, it is traditionally cultivated on a commercial scale in the states of Andhra Pradesh, West Bengal, Kerala and Tamil Nadu. In West Bengal, elephant foot yam is successfully grown as a remunerative vegetable and harvested mainly for its corms. Leaves are also consumed in many areas. The most popular variety is Bidhan Kusum. Rainfed elephant foot yam is generally planted during the month of June with the onset of monsoon. This is still being practiced by traditional farmers in sporadic pockets in the state and the area under this crop is on the decline. Under intensive cropping, in the Ganges delta, the irrigated crop is planted during the summer months of March and April. But widespread contamination of arsenic (As) in groundwater in different parts of West Bengal has become the source of As in the food chain, through irrigation. The nature of corm bulking in elephant foot yam offers scope for As accumulation. Studies indicate that chronic As poisoning can cause serious health hazards in human beings including cancer, hyperkeratosis, restrictive lung disease, peripheral vascular disease and ischemic heart disease (Guha-Mazumder et al., 2000; Morales et al., 2000). In West Bengal, As contamination is reported in 111 blocks distributed over 12 districts. The ground water As concentration (50-1600 $\mu g\ l^{-1}$), reported from the affected areas of West Bengal are several orders of magnitude greater than the stipulated Indian standard for the permissible limit in drinking water (50 $\mu g\ l^{-1}$) (WHO, 1993; CGWB, 1999; Ghosh et al., 2004). The Joint FAO/WHO Expert Committee on Food Additives (JECFA) set a provisional maximum tolerable daily intake (PMIDI) of inorganic As as 2 $\mu g\ kg^{-1}$ of body weight for humans in 1983.

The source of As in water is geogenic and the problem seems to be triggered off by large-scale withdrawal of groundwater for irrigation during the lean period when the groundwater recharge is at its minimum (Mandal et al., 1996; Sanyal, 2005). Uptake of As by crop plants grown in soils contaminated with high concentrations of As and irrigated with As contaminated water has been reported by Abedin et al. (2002). Presence of As in vegetables and tubers crops and its translocation to the edible parts were observed to vary with crops (Alam et al., 2003) and even among the cultivars of the same crop (Kundu et al., 2011). Harvested rain water in ponds contains less As than groundwater and results in less As uptake in plants. Organic management results in the formation of metal-humate complexes (Datta et al., 2001), leading to less availability of As to the crop. Presence of phosphate competes with arsenate uptake in soil-plant systems due to the greater affinity towards phosphate compared to arsenate (Abedin et. al., 2002). The objectives of the study were to assess the extent of As contamination in the crop of elephant foot yam and to explore the possibilities of reducing the accumulation through nutrient management and irrigation using harvested rain water.

Materials and Methods

The experiment was conducted in farmers' field at Nonaghata-Uttarpara village (22°57'N latitude, 89°33'E longitude), Haringhata block, Nadia district, West Bengal, India, during 2009 and 2010. The climate of the experimental site is humid subtropical. The soil is silty clay loam. The soil pH was 6.65 and total As concentration was 16.52 mg kg^{-1}. The initial soil organic C was 0.64%, available N 172 kg ha^{-1}, available P 43 kg ha^{-1} and available K 115 kg ha^{-1}. The As content of irrigation water from shallow tube well (STW) was 0.122-0.169 mg l^{-1} and pond water (PW) contained As to the extent of 0.014-0.056 mg l^{-1}. The test crop was elephant foot yam var. Bidhan Kusum. The crop was planted during early April and harvested at the end of October and in effect received five irrigations before the onset of monsoons and one to two irrigations beyond the monsoon. The crop was irrigated according to its requirement. The experiment was laid out in split plot with two irrigation sources (I_1: irrigation from shallow tube well water (STW) and I_2: irrigation from pond water (PW)) in main plots and four nutrient management options [N_1: 100% RDF (NPK @ 200:120:140 kg ha^{-1}) + FYM @ 10 t ha^{-1}, N_2: 100% RDF + higher dose of P (double the dose of recommended) (NPK @ 200:240:140 kg ha^{-1}) + FYM @ 10 t ha^{-1}, N_3: 75% RDF (NPK @ 150:90:105 kg ha^{-1}) + FYM @ 10 t ha^{-1}, N_4: 75% RDF + higher dose of P (NPK @ 150:180:105 kg ha^{-1}) + FYM @ 10 t ha^{-1}] in sub plots, replicated thrice. The net plot size was 4m × 3m.

The plant samples were collected at harvest and they were separated into petiole (pseudostem), leaves and corms. The plant samples were dried at 60°C for 48 hours. Dried and ground plant samples were digested with tri-acid mixture (HNO_3: H_2SO_4: $HClO_4$: 10: 1: 4, v/v) until a clear solution was obtained. These digests were filtered using Whatman No. 42 filter paper. Ten ml of the filtrate was taken and 5 ml concentrated HCl and 2 ml 10% KI-ascorbic acid solution were added. The total As content in the solution was determined by using AAS (Perkin Elmer Analyst 200) coupled with FIAS 400.

Results and Discussion

It was observed that there was no significant difference in corm yield (32-33 t ha^{-1}) due to the water sources

Table 1. Main and interaction effects of irrigation sources and nutrient management on corm yield of elephant foot yam

Treatment	Corm yield (t ha^{-1})			Treatment	Corm yield (t ha^{-1})		
	2009	2010	Pooled		2009	2010	Pooled
	Irrigation source				Interaction effect		
I_1	32.25	33.16	32.75	I_1N_1	32.41	30.30	31.36
I_2	33.69	33.82	33.75	I_1N_2	30.29	29.54	29.92
C.D (0.05)	NS	NS	NS	I_1N_3	35.81	36.94	36.38
	Nutrient management			I_1N_4	36.08	37.04	36.56
N_1	32.61	30.78	31.69	I_2N_1	32.81	31.25	32.03
N_2	30.07	29.28	29.68	I_2N_2	29.85	29.02	29.44
N_3	35.81	37.03	36.42	I_2N_3	35.81	37.11	36.46
N_4	36.18	37.46	36.82	I_2N_4	36.28	37.88	37.08
C.D (0.05)	1.708	3.411	1.807	C.D (0.05)	NS	NS	NS

I_1 = irrigation from shallow tube well, I_2 = irrigation from pond, N_1 = 100% RDF + FYM @10 t ha^{-1}, N_2 = 100% RDF + higher dose of P (double the recommended dose) + FYM @10 t ha^{-1}, N_3 = 75% RDF + FYM @10 t ha^{-1}, N_4 = 75% RDF + higher dose of P + FYM @10 t ha^{-1}, NS = not significant

used for irrigation during the two years (Table 1). Pooled analysis also indicated similar results. The As content in the soil and water of the location might have not exceeded the permissible limit to register crop yield reduction. It might also be due to the tolerant nature of elephant foot yam to As contamination (Adriano, 1986). Among the nutrient management options, 75% RDF + higher dose of P + FYM @ 10 t ha^{-1} (N_4) produced highest corm yield (36.82 t ha^{-1}), which was on par with N_3 (36.42 t ha^{-1}). Supply of available P was greater in N_4 and the effect of FYM also contributed to greater P solubility (Quastel, 1965) and soil improvement (Singh et al., 1981). The minimum yield was produced by 100% RDF with higher dose of P (N_2). The interaction between irrigation and nutrient management options was not significant for corm yield.

Among the plant parts analysed, As content was maximum in the pseudostem followed by leaves and was least in the corms (Table 2). The As accumulation in

Table 2. Effect of irrigation sources and nutrient management on arsenic content in elephant foot yam

Treatment	Arsenic content (mg kg^{-1})								
	Leaves			Pseudostem			Corm		
	2009	2010	Pooled	2009	2010	Pooled	2009	2010	Pooled
Irrigation source									
I_1	1.33	1.35	1.34	2.65	2.68	2.67	0.37	0.37	0.37
I_2	1.18	1.19	1.18	2.57	2.54	2.55	0.35	0.33	0.34
C.D (0.05)	NS	0.030	0.134	NS	0.085	0.086	0.012	0.012	0.004
Nutrient management									
N_1	1.45	1.56	1.49	2.87	3.15	3.00	0.38	0.42	0.40
N_2	1.19	1.23	1.22	2.54	2.51	2.52	0.37	0.36	0.36
N_3	1.30	1.27	1.29	2.66	2.58	2.63	0.36	0.35	0.35
N_4	1.09	1.03	1.06	2.36	2.19	2.27	0.33	0.27	0.30
C.D (0.05)	0.046	0.009	0.023	0.086	0.071	0.082	0.006	0.006	0.003

I_1 = irrigation from shallow tube well, I_2 = irrigation from pond, N_1 = 100% RDF + FYM @10 t ha^{-1}, N_2 = 100% RDF + higher dose of P (double the recommended dose) + FYM @10 t ha^{-1}, N_3 = 75% RDF + FYM @10 t ha^{-1}, N_4 = 75% RDF + higher dose of P + FYM @10 t ha^{-1}, NS = not significant

Table 3. Interaction effect of irrigation sources and nutrient management on arsenic content in elephant foot yam

Treatment	Arsenic content (mg kg^{-1})								
	Leaves			Pseudostem			Corm		
	2009	2010	Pooled	2009	2010	Pooled	2009	2010	Pooled
I_1N_1	1.58	1.69	1.64	2.97	3.26	3.11	0.39	0.45	0.42
I_1N_2	1.23	1.30	1.26	2.54	2.56	2.55	0.36	0.37	0.37
I_1N_3	1.40	1.36	1.38	2.69	2.62	2.65	0.37	0.37	0.37
I_1N_4	1.12	1.04	1.09	2.38	2.28	2.34	0.34	0.28	0.31
I_2N_1	1.32	1.42	1.36	2.77	3.04	2.91	0.37	0.39	0.38
I_2N_2	1.14	1.16	1.15	2.54	2.46	2.51	0.34	0.34	0.34
I_2N_3	1.20	1.17	1.18	2.62	2.54	2.57	0.35	0.32	0.34
I_2N_4	1.05	1.01	1.03	2.34	2.10	2.23	0.32	0.26	0.29
C.D (0.05)	0.064	0.015	0.043	0.114	0.093	0.105	0.006	0.009	0.006

I_1 = irrigation from shallow tube well, I_2 = irrigation from pond, N_1 = 100% RDF + FYM @10 t ha^{-1}, N_2 = 100% RDF + higher dose of P (double the recommended dose) + FYM @10 t ha^{-1}, N_3 = 75% RDF + FYM @10 t ha^{-1}, N_4 = 75% RDF + higher dose of P + FYM @10 t ha^{-1}, NS = not significant

leaves was roughly five times that of corms and half that in pseudostems. The pattern of As accumulation followed the order corms < leaves < pseudostem. Interestingly, earlier studies by Chang et al. (2006) showed that most As was found in the roots. Tlustos et al. (2002) also reported higher As in spinach roots. Arsenic accumulation in leaves (1.18 mg kg^{-1}), pseudostems (2.55 mg kg^{-1}) and corms (0.34 mg kg^{-1}) was significantly lower when pond water was the irrigation source compared to shallow tube well irrigation.

The maximum accumulation of As in pseudostems, leaves and corms was observed in N_1 treatment (Table 2). Arsenic accumulation in corms was significantly lowest in N_4 (0.30 mg kg^{-1}) followed by N_3 (0.35 mg kg^{-1}). Leaves and pseudostem accumulated significantly lowest quantity of As in N_4 (1.06 and 2.27 mg kg^{-1} respectively) followed by N_2 (1.22 and 2.52 mg kg^{-1}respectively) indicating application of organic manures like FYM and reduction in inorganic fertilisers, especially N and K, reduced As accumulation. Inclusion of FYM in the nutrient schedule was responsible for more P mobilization by formation of phospho-humic complexes, which was easily assimilated by plants (Sanyal and Nassar, 2002). Moreover, anion replacement of the phosphate by humate ion and coating of sesquioxide particle by humus to form a protective cover might have reduced P fixation in the soil (Tisdale et al., 1990), enhancing P accumulation and thereby reducing As uptake.

The same trend as that of the main effects were observed in the case of interaction between sources of irrigation and nutrient management options. The As accumulation in the various plant parts was significantly lowest in I_2N_4, i.e., irrigation using pond water in conjunction with application of 75% RDF + higher dose of P + FYM @ 10 t ha^{-1} (Table 3).

Conclusion

Irrigation using pond water significantly reduced the As contamination in plant parts compared to groundwater irrigation in elephant foot yam. The As contamination in edible portion was least when major nutrients were supplemented with FYM and when higher dose of P was used. Supplementation of fertilizer dose with FYM, with or without higher dose of P (N_4 and N_3) also produced comparable yields. Reducing the inorganic source of nutrients by 25% and supplementing with FYM @10 t ha^{-1} produced higher corm yield with lesser As contamination.

References

Abedin, M.J., Cresser, M.S., Mcharg, A.A., Feldmann, J. and Howells, J.C. 2002. Arsenic accumulation and metabolism in rice (*Oryza sativa* L.). *Environmental Sci. Technol.,* 36: 962-968.

Adriano, D.C. 1986. *Trace Elements in Terrestrial Environment*. Springer-Verlag, New York.

Alam, M.G.M., Snow, E.T. and Tanaka, A. 2003. Arsenic and heavy metal contamination of vegetables grown in Samta village, Bangladesh. *Sci. Total Environment*, 308 (1/3): 83-96.

CGWB. 1999. *High Incidence of Arsenic in Groundwater in West Bengal*, Central Groundwater Board, Ministry of Water Resources, Government of India, India.

Chang, S., Jia D., Tian Z. and Ma, X. 2006. Effects of arsenic application on absorption, accumulation and distribution of arsenic in flue-cured tobacco. *J. Henan Agric. Univ.*, 40 (5): 486-489.

Datta, A., Sanyal, S.K. and Saha, S. 2001. A study on natural and synthetic humic acids and their complexing ability towards cadmium. *Pl. Soil,* 235: 115-125.

Ghosh, K., Das, I., Saha, S., Banik, G.C., Ghosh, S., Maji, N.C. and Sanyal, S.K. 2004. Arsenic chemistry in groundwater in the Bengal Delta Plain: Implications in agricultural system. *J. Indian Chem. Soc.,* 81: 1063-1072.

Guha-Mazumder, D.N., Haque, R., Ghose, N., De, B.K., Santra, A. and Chakraborty, D. 2000. Arsenic in drinking water and the prevalence of respiratory effects in West Bengal, India. *Int. J. Epidemiology*, 29: 1047-1052.

Kundu, R., Pal, S. and Bandopadhyay, P. 2011. Response of taro to arsenic contamination in the Ganga basin of Eastern India. *J. Root Crops*, 37 (2):168-173.

Mandal, B.K., Chowdhury, T.R., Samanta, G., Basu, G.K., Chowdhury, P. P., Chanda, C.R., Lodh, D., Karan, N.K., Dhara, R.K., Tamili, D.K., Das, D., Saha, K.C. and Chakraborti, D. 1996. Arsenic in groundwater in seven districts of West Bengal, India – The biggest arsenic calamity in the world. *Curr. Sci.,* 70: 976-986.

Morales, K.H., Ryan, L., Kuo, T.L., Wu, M.M. and Chen, C.J. 2000. Risk of internal cancers from arsenic in drinking water. *Environmental Health Perspectives*, 108: 655-661.

Quastel, J. H. 1965. Soil metabolism. *Ann. Rev. Pl. Physiol.,* 16: 217-240.

Sanyal, S.K. 2005. Arsenic contamination in agriculture: A threat to water-soil-crop-animal-human continuum. *Presidential Address, Section of Agriculture and Forestry Sciences, 92nd Session of the Indian Science Congress Association*. Ahmedabad, Gujarat, India.

Sanyal, S.K. and Nassar, S.K.T. 2002. *Analysis and Practice in Water Resources Engineering for Disaster Mitigation*. New Age International (P) Limited, New Delhi, pp. 216-222.

Singh, B.P., Chahal R.S. and Singh, M. 1981. Fertilizer management through organic and inorganic fertilizers in bajra- wheat crop sequences. *Fert. News,* 26 (8): 16-19.

Tisdale, S.L., Nelson, W.L. and Beaton, J.D. 1990. *Soil Fertility and Fertilizers*, Macmillan. New York.

Tlustos, P., Szakova, J., Pavlikova, D., Balik, J. and Hanc, A. 2002. The accumulation of arsenic and cadmium by different species of vegetables. *Acta Horticulturae,* 571: 217-224.

WHO. 1993. *Guidelines for Drinking Water Quality*. 2nd Edn., World Health Organization, Geneva, Rome, Italy.