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Reduction of Arsenic Load in Winter Fodder Crops as Influenced by Shallow Tube Well and Pond Water Irrigation

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

An experiment was conducted in the farmer's field located at latitude is N 23º1′19.9′′ and longitude is E 88º34′31.8′′ in an arsenic affected village Goentra of west Bengal, India during winter season 2009-10, 2010-11 and 2011-12. In arsenic contaminated village of Goentra, the wide variation of arsenic in shallow tube well water and pond water was observed. The level of variation is almost three times more in shallow tube well water as compare to the pond water. Rain water harvested pond water (0.04 mg L^{-1}) is safer than the underground source of water (0.14 mg L^{-1}). The experiment was conducted in factorial experiment in split-split plot design. Two fodder crops were

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laid as main plot, i.e. Oats and lucerne, two sources of irrigation i.e. pond water and shallow tube well water was in sub plot and frequency of irrigation was three in sub-sub plot. The crops was, therefore, tested against two source of irrigations viz.: (i) Pond water and (ii) shallow tube well water; and frequency of irrigation water viz.: (i) Irrigation at 20 DAS, (ii) Irrigation at 20 and 35 DAS and (iii) Irrigation at 20, 35 and 50 DAS. The Lucerne fodder crop received comparatively less arsenic uptake than oats fodder. Pond water irrigated fodder crops shows significantly less arsenic concentration in plant parts comparatively to shallow tube well water irrigated fodder crops. Shoots arsenic content reduction with once irrigation is 11.93 % whereas in two irrigations shoots arsenic content is only 4.0 % at harvest stage of crops. The frequency of irrigation considerably shows the arsenic concentration variation in fodder crops. The fodder crops irrigated with single irrigation shows less arsenic (2.97 mg kg^{-1}) in plant than the two or three irrigation.

Keywords: Arsenic content; water source; irrigation frequency; oats; lucerne.

1. INTRODUCTION

The oats is cereal fodder crops oats is whereas lucerne is legumes fodder crops grown arsenic affected areas of West Bengal. During winter, fodder crops needs irrigation i.e. pond water and shallow tube well water. The farmers mostly used shallow and deep tube well water in affected areas for irrigation to the winter fodder crops. It has gained a serious magnitude due to arsenic uptake [1]. Green fodder is an important component of livestock feed and nutrition. Arsenic concentration in soil, water, plant parts, fodder and forage crops is found beyond the permissible limit. According to the European Union [2] standardized a maximum acceptable concentration (MAC) of 2 mg kg^{-1} for arsenic in complete feedstuffs. In recent times arsenic (As) contamination of groundwater in the Gangetic alluvial zone of West Bengal (covering about 39,000 sq. km area) has arrested considerable amount of attention as millions (9-10 millions) of people is suffering from this menace. The As concentration in groundwater (50 – 1600 μg/L), reported from the affected areas of West Bengal, are several orders of magnitude higher than the stipulated Indian standard for the permissible limit in drinking water (50 μg/L, which is also the maximum acceptable concentration, MAC, for drinking water in Bangladesh, India and several other countries), as well as the WHO guideline value (10 μg/L) [3, 4]. There have possibility to supply rain water harvested pond water as irrigation which is arsenic free water. Bhattacharya et al. [5] reported that the use of rainwater for irrigation in aerobic rice is some possible ways to reduce the extent of bioaccumulation of arsenic. The arsenic contamination is high in all sources of water, plant parts, and food in contaminated areas of West Bengal. The major issues are that the agricultural produces not utilized by local peoples but it is marketed or exported to distance places. Similarly, fodder crops grown in contaminated areas; fodder is fed by milch animal subsequently the milk is transported to metro cities. Millions of animals and human are affected with arsenic through food chain [6]. The level of arsenic species influences the arsenic food toxicity [7]. The main objective of our experiment was to reduce arsenic load in fodder crops through use of less arsenic uptake fodder crop, pond water and frequency of irrigation water.

2. MATERIALS AND METHODS

An experiment was conducted in the farmer's field in an arsenic affected village at Ghentugachhi of West Bengal, India during winter season 2009-2010, 2010-2011 and 2011-2012. The total arsenic content of the shallow tube well water was in the range of 0.116-0.127 mg L^{-1} with a mean value of 0.120 mg L^{-1} and total arsenic content in pond water was in range of 0.039-0.041 mg L^{-1} with mean value 0.040 mg L^{-1}. Arsenic status in arsenic affected areas was taken four samples before sowing of the fodder crops viz. 14.32, 15.49, 14.45 and 15.90 mg Kg^{-1} in same experimental plot of different location with mean value of 15.04 mg Kg^{-1}.

The variety of oats was OS-6 and lucerne variety T-9 was selected for the study area. The fodder crops were sown in first week of December after taking rice and green fodder was harvested at 60 days after sowing. The experiment was laid out in factorial experiment in split-split plot design. Two fodder crops were laid as main plot, i.e. Oats and lucerne, two sources of irrigation i.e. Pond water and shallow tube well water was in sub plot and frequency of irrigation was three in sub-sub plot. The crops was, therefore, tested against two source of irrigations viz.: (i) Pond water and (ii) shallow tube well water; and frequency of irrigation water viz.: (i) Irrigation at

20 DAS, (ii) Irrigation at 20 and 35 DAS and (iii) Irrigation at 20, 35 and 50 DAS. So, for each experiment, number of total treatments was 12 and replicated thrice.

The whole plant sample were collected at different growth stages, i.e. at 30, 45, 60 days after sowing. The soil samples were air-dried, ground and sieved through a 2 mm sieve and packed in airtight polythene containers. The plant samples were oven dried for 24 h at 105 ◦C, ground and packed in airtight polythene containers. For estimation of total arsenic, plant and soil samples; were digested with tri-acid mixture (HNO_3: H_2SO_4: $HClO_4$ = 10: 1: 4, by volume) after an overnight pre-digestion. Digestion was done in sand bath at a temperature of 120 ˚C for two hours until a clear solution was obtained. The solution was then filtered with Whatman number 42 filter paper and volume was made up to desired amount. After adequate dilution, if needed, the solution was reduced with 5% mixture of KI and ascorbic acid prior to analysis and finally measured for total As by a Perkin Elmer AANALYST 200 atomic absorption spectrophotometer (Model: Perkin Elmer AANALYST 200) coupled with Flow Injection Analysis System (FIAS 400). The data obtained as described earlier were subjected to statistical analysis by the Analysis of Variance method and the significance of different sources of variations were tested by Error of Mean Square by Fisher and Snedecor's 'F' test at probability level 0.05.

3. RESULTS AND DISCUSSION

Temporal variation in arsenic content of fodder crops were estimated on 30, 45 and 60 days after sowing. Data base was generated for three consecutive years. The shoots arsenic (As) content was observed with oats at 30, 45 DAS and harvest stage with values pooled over three years of 1.766 mg kg^{-1}, 2.317 mg kg^{-1} and 3.550 mg kg^{-1} respectively (Table 1). Whereas in lucerne crops shoots As content was observed at 30, 45 DAS and harvest stage with pooled value over three years of 1.682 mg kg^{-1}, 2.210 mg kg^{-1} and 3.380 mg kg^{-1} respectively (Table 1).

Pond water (PW) intervention significantly lowered shoots as content, having minimum values of 3.358 mg Kg^{-1}, 3.420 mg Kg^{-1} and 3.406 mg Kg^{-1} at 60 days after sowing (DAS) in the successive years of experiment and pooled value over three years was observed 3.395 mg Kg^{-1} at harvest stage of crops. STW (Shallow tube well) water intervention significantly higher shoots arsenic content, having pooled value over three years of 3.535 mg Kg^{-1} at harvest stage. Arsenic content in shoots was noticed 4.12 % less in plot where irrigation with PW (Pond water) than STW at harvest stage (Table 1).

The shoots arsenic content by I_3 was significantly more than I_1 and I_2 at 45 DAS and harvest stage. Experiment shows the maximum shoots arsenic content in I_3 treatment. Two irrigations show significantly less shoots arsenic content. Shoots arsenic content reduction with once irrigation is 11.93 % whereas in two irrigations shoots arsenic content is only 4.0 % at harvest stage of crops [8]. At 45 days after sowing I_2 and I_3 treatments observed near about similar shoots arsenic content because of at 45 DAS only two irrigations was received by crops (Table 1).

Shoots As content reduced significantly across the stages when oats was in receipt of pond water irrigation and the advantage was significant over corresponding lowering of As accumulation with the similar treatment combinations at harvest stage. Shoots As content reduced significantly across the stages when lucerne was in receipt of pond water irrigation and the advantage was significant over corresponding lowering of as accumulation with the similar treatment combinations. The maximum shoots as content (3.602 mg Kg^{-1}) was recorded in C_1S_2 treatment combination value pooled over three years at harvest stage (Fig. 1).

Fodder crops in combination with frequency of irrigation exhibited lower as accumulation with I_1 and I_2 levels than with I_3. Lucerne obtained greater advantage in reducing shoots as content (3.409 mg Kg^{-1} and 3.147 mg Kg^{-1} at 60 DAS values pooled over three years) when in combination with I_1 and I_2 and recorded significantly lower as content over oats with similar combinations in the respective years of experiment. The maximum shoots As content (3.697 mg Kg^{-1}) was recorded in C_1I_3 treatment combination value pooled over three years at harvest stage (Fig. 2).

This interaction effect was significant only at harvest stages and in all the years of experiment. The combination of pond water (S_1) and I_1 found to accumulate less As in shoots having values 3.066 mg Kg^{-1} in 2009-10 at 60 DAS followed by 3.416 mg Kg^{-1} with the combination of pond water (S_1) and I_2. The maximum As accumulation was observed with combination of Shallow tube well (S_2) and I_3 at 60 DAS with values of 3.678 mg Kg^{-1} (Fig. 3).

Table 1. Effects of fodder crops, source of irrigation and frequency of irrigation on arsenic content of shoots (mg kg^{-1}) of oats and lucerne at various stages of crop growth

Treatments	Arsenic in shoots (mg kg^{-1})											
	30 DAS				45 DAS				60 DAS (Harvest stage)			
	2009-10	2010-11	2011-12	Pooled	2009-10	2010-11	2011-12	Pooled	2009-10	2010-11	2011-12	Pooled
Fodder Crops												
C_1	1.759	1.772	1.766	1.766	2.311	2.316	2.325	2.317	3.540	3.556	3.554	3.550
C_2	1.681	1.687	1.677	1.682	2.215	2.213	2.200	2.210	3.352	3.392	3.396	3.380
S. Em (±)	0.009	0.007	0.008	0.008	0.012	0.006	0.008	0.009	0.005	0.008	0.009	0.007
C.D (5 %)	0.055	0.046	0.046	0.049	0.074	0.039	0.050	0.054	0.028	0.050	0.054	0.044
Source of irrigation												
S_1	1.670	1.676	1.676	1.674	2.205	2.208	2.214	2.209	3.358	3.420	3.406	3.395
S_2	1.770	1.783	1.768	1.773	2.321	2.322	2.310	2.318	3.534	3.528	3.544	3.535
S. Em (±)	0.007	0.004	0.004	0.005	0.005	0.013	0.008	0.009	0.010	0.006	0.008	0.008
C.D (5 %)	0.027	0.014	0.016	0.019	0.020	0.052	0.031	0.034	0.039	0.022	0.030	0.030
Frequency of irrigation												
I_1	1.721	1.732	1.731	1.728	2.086	2.083	2.076	2.082	3.227	3.269	3.263	3.253
I_2	1.720	1.727	1.717	1.721	2.353	2.353	2.355	2.354	3.481	3.506	3.517	3.501
I_3	1.720	1.730	1.717	1.722	2.350	2.358	2.356	2.355	3.631	3.647	3.646	3.641
S. Em (±)	0.006	0.006	0.005	0.006	0.007	0.013	0.014	0.011	0.011	0.012	0.007	0.010
C.D (5 %)	**NS**	**NS**	**NS**	**NS**	0.021	0.040	0.041	0.034	0.034	0.035	0.022	0.030

C_1= Oats, C_2= Lucerne, S_1= Irrigation from Pond water, S_2= Irrigation from Shallow tube well water, I_1= One irrigation at 20 days after sowing, I_2= First irrigation at 20 days after sowing and second irrigation at 35 days after sowing, I_3= First irrigation at 20 days after sowing, second irrigation at 35 days after sowing and third irrigation at 50 days after sowing, DAS= Days after sowing, NS= Not significant.

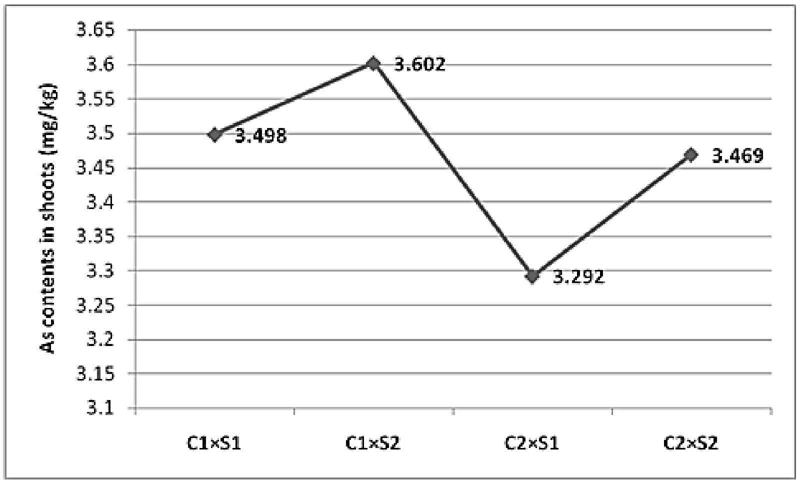

Fig. 1. Interaction effects of fodder crops and source of irrigation on arsenic content of shoots (mg kg^{-1}) of oats and lucerne at various stages of crop growth

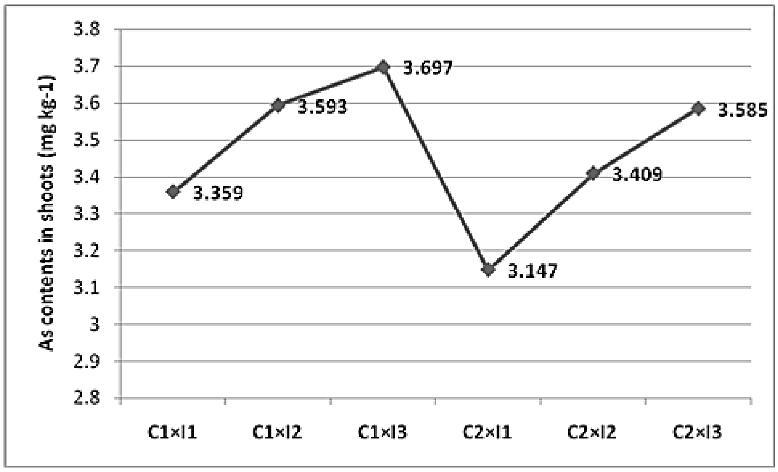

Fig. 2. Interaction effects of fodder crops and frequency of irrigation on arsenic content of shoots (mg kg^{-1}) of oats and lucerne at various stages of crop growth

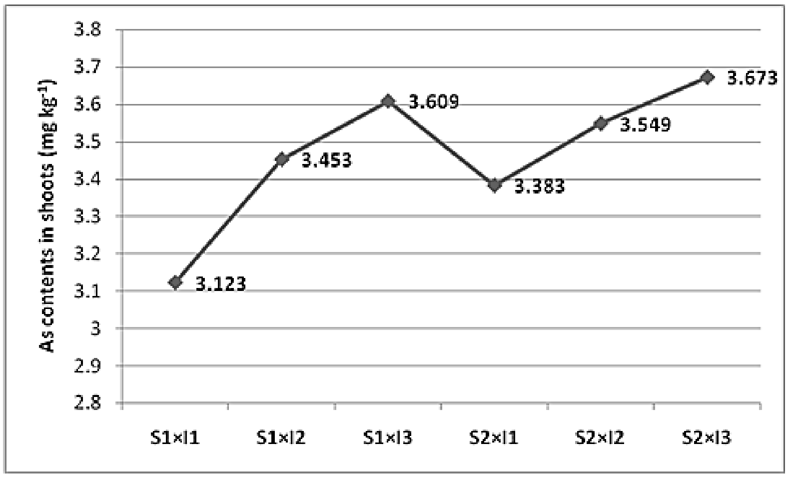

Fig. 3. Interaction effects of source of irrigation and frequency of irrigation on arsenic content of shoots (mg kg^{-1}) of oats and lucerne at various stages of crop growth

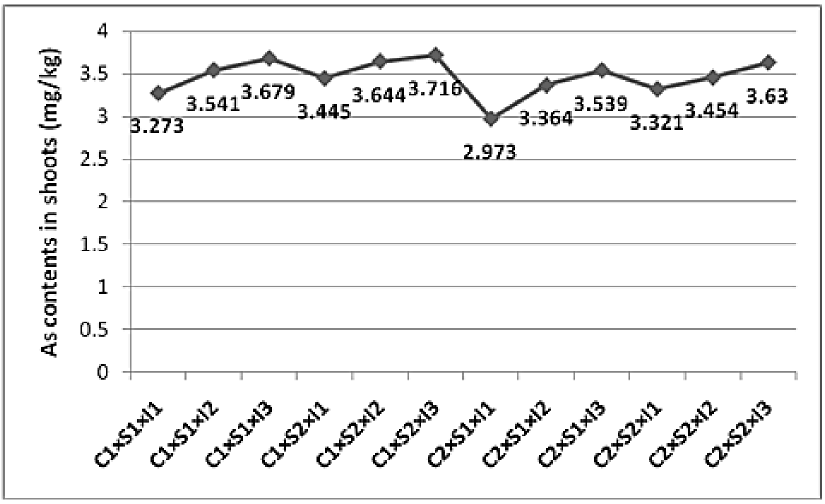

Fig. 4. Interaction of treatments on arsenic content of shoots (mg kg^{-1}) of forage crops

The interaction of fodder crops, irrigation sources and frequency of irrigation was significant in harvest stages and all the years of experiment. $C_2S_1I_1$ treatment combination was proved to be the best combination over the others that recorded the lowest as accumulation at harvest stage 2.97 mg kg^{-1} pooled over three years. The maximum as accumulation was observed with $C_2S_2I_3$ treatment combination at 60 DAS with value pooled over three years of 3.630 mg Kg^{-1} (Fig. 4). The present experiment indicates that lucerne legumes fodder crop observes comparatively less arsenic uptake than oats cereal fodder. Pond water irrigated fodder crops shows significantly less arsenic concentration in plant parts comparatively to shallow tube well water irrigated fodder crops. The frequency of irrigation considerably shows the arsenic concentration variation in fodder crops. The fodder crops irrigated with single irrigation shows less arsenic (2.97 mg kg^{-1}) in plant than the two or three irrigation. Rosas *et. al.* [9] also reported the arsenic load from soil and water is transported to the forage crops. This trend supported the findings of [10, 11] 2012 respectively for sesame and rice crops, grown in the same location.

4. CONCLUSION

From the present investigation it is concluded that lucerne legumes fodder crop observes comparatively less arsenic uptake than oats cereal fodder. Pond water irrigated fodder crops shows significantly less arsenic concentration in plant parts comparatively to shallow tube well water irrigated fodder crops. The frequency of irrigation considerably shows the arsenic concentration variation in fodder crops as less number of irrigation contribute less arsenic load in feed stuff where more number of irrigation more arsenic load in green fodder.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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