Journal of
Plant Science & Research

Open Science Publications

Volume 1, Issue 2 - 2014

www.opensciencepublications.com

Consequences of Arsenate Exposure on Important Yield-Associated Traits of Rice (*Oryza Sativa* L.)

Research Article

M. K. Bag[1]*, B. Adhikari[1], S. Dwivedi[2] and R. D. Tripathi[2]

[1]*Rice Research Station, Chinsurah R.S., West Bengal 712 102, India*
[2]*National Botanical Research Institute, Lucknow, U.P.226 001, India*

***Corresponding author:** Manas Kumar Bag, National Bureau of Plant Genetic Resources, New Delhi, 110012, India, E-mail: manas.bag@gmail.com; manas@nbpgr.ernet.in

Article Information: **Submission:** 06/06/2014; **Accepted:** 09/07/2014; **Published:** 11/07/2014

Abstract

A pot experiment under simulated arsenic (As) condition with different doses of arsenate (As^V) [4, 8, 12 mg l^{-1} and control] was done on four popular rice (*Oryza sativa* L.) varieties viz. Triguna, IR 36, PNR 519 and IET 4786 (Satabdi) to find out the grain As levels and changes of other phenotypes / physiological characteristics. With the increase of As^V concentration in soil, the number of tillers increased in Triguna and IR 36 up to 8 mg l^{-1} while PNR 519 and IET 4786 (Satabdi) exhibited a less number of tillers when exposed to different doses of As^V concentration. The average plant height of these varieties also showed a similar trend and it increased up to 4 mg l^{-1} in Triguna and IR 36 and IET 4786 (Satabdi) but PNR 519 was found inhibitory. In contrast, seed weight of all the varieties was found to have increased with the increase in concentration As^V upto 8 mg l^{-1}. In general, As^V exposure had led to early flowering in rice cultivars and consequently early seed maturity in almost all the cultivars.

Keywords: AsV dose; Phenotypic characters, Pot experiment

Introduction

Arsenic (As), a carcinogenic metalloid has become a global concern due to its ever-increasing contamination in many regions in the world particularly in South East Asia. It is reported that there was a strong dose-response relationship between As exposure and clinical signs, i.e. malanosis, edema and skin, lung and urinary tract cancers in As-affected regions of West Bengal (India) and Bangladesh [1]. Rice (*Oryza sativa* L.) has been reported to accumulate up to 1.8 mg kg^{-1} As in grains and up to 92 mg kg^{-1} in straw [2]. Besides drinking water, rice that contributes more than 60% of human diet is one of the main cause of As-exposure to the people of As-contaminated regions of South-East Asia [3].

The total As concentration in rice varies from 0.005 to 0.710 mg kg^{-1} dw in different varieties and it also differs from one geographical region to other e.g. <0.01-2.05 in Bangladesh, 0.31-0.76 in China, 0.03-0.44 in India and 0.11-0.66 in USA [4]. Consequently rice is a major crop been cultivated in the areas where severe As contamination exists including Bangladesh, West Bengal (India), Taiwan and China [5]. It is reported that this element is not only non-essential to the plant but also interfere with various metabolic process that cause physiological and morphological disorders at higher doses leading to inhibit plant growth and death [6].

In this backdrop, to study the effect of As on yield-associated traits, a pot experiment under simulated As condition was conducted on four popular and widely cultivated rice varieties.

Materials and Methods

A pot experiment in a simulated As condition was conducted at Rice Research Station, Chinsurah (latitude 22°53´44″N; longitude 88°24´9″E), West Bengal, India during *Boro* 2008-09 and 2009-10. Four popular HYVs of rice viz., Triguna, IR 36, PNR 519 and IET 4786 (Satabdi) were selected for the experiment. Grains were allowed to germinate after surface sterilization (by 0.1% $HgCl_2$ for 1 min).

ISSN: 2349-2805

Reviewed & Approved by Dr. Altafhusain B Nadaf, Associate Professor, Department of Botany, University of Pune, India

Transplanting was done with the 21 days old seedlings. Three seedlings (1 seedlings /hill) of each cultivar were planted at three different places of one pot (14″ earthen pot) under natural light and humid conditions in net house. Pots were watered daily with deionized water to maintain water logging condition. During tillering, pre-flowering and post-flowering stages the plants were irrigated with different arsenic concentrations (4, 8 and 12 mg l^{-1} As) using Na_2HAsO_4 and one control [without arsenate (As^V)] was taken as check. Different concentrations were made in 3 litres of deionised water and supplied twice in a day at the above mentioned stages.

Protocol of Dwivedi *et al.* [7] was followed for estimation of As. The level of Fe, Zn, and As were quantified by Inductively Coupled Plasma Mass Spectrometer (ICP-MS, Agilent 7500ce) at National Botanical Research Institute, Lucknow, India. pH and EC of soil were measured by ion meter (Orion, USA), while water holding capacity was measured by hydrometry.

All the experiment was conducted following a randomized block design. Two way analysis of variance (ANOVA) and Duncan's multiple range test (DMRT) was performed to determine the significant difference between treatments and genotypes. Correlation analysis was performed following Gomez and Gomez [8]. All the data of each cultivar with respect to changes in metal content or between parameters, has been given within the text at relevant places ($p<0.001$***; $p<0.01$**; $p<0.1$*; NS nonsignificant).

Results and Discussion

The physico-chemical characterisation of soil used during pot experiment along with variations due to the irrigation of different concentration of As^V is presented in Table 1. The pH of control soil was slightly alkaline (7.6) which decreased after repeated loading of 4, 8 and 12 mg l^{-1} of As^V. The soil is rich in phosphorus (447.42 mg kg^{-1}) and availability of P fortified with addition of 4 mg l^{-1} As^V (725.69 mg kg^{-1}) and further decrease at higher dose of As^V but this level is higher than control. The natural As^V concentration in control soil was low (2.3 mg kg^{-1} dw) which increased upto 31 mg kg^{-1} dry weight (dw) by irrigation of 12 mg l^{-1} As^V. It was 24 and 26 mg kg^{-1} dw at 4 and 8 mg l^{-1} respectively. No changes were observed in case of other metals like Fe, Zn and S. Availability of nitrogen in natural soil was 0.49% and increased up to 1.18% at 4 mg l^{-1} As^V and further decreased to 0.8% and 0.9% respectively at 8 and 12 mg l^{-1} As^V. Various growth parameters were determined. Growth variables of selected rice cultivars have been presented in figure 1A-D. The number of tillers was found to be a varietal characters which ranged from 17-22 in different rice cultivars, however, number of tillers increased in all the cultivars when 4 mg l^{-1} As^V was added in the soil except Triguna where number of tillers increased upto 8 mg l^{-1} As^V but decreased significantly at higher As^V supply (Figure 1 A). There was no significant change observed in terms of plant height and panicle length up to 4 mg l^{-1} As but at higher As^V doses (8 and 12 mg l^{-1}), significant decrease in plant height and panicle length were noticed (Figure 1 B, C) in all the varieties except in IET 4786 (Satabdi). In case of IET 4786 (Satabdi) plant height was decreased with increasing concentration of As^V supply in the soil and panicle length was decreased significantly only at 12 mg l^{-1} of As^V supply. Similarly, grain weight (Figure 1D) was increased by As^V supply only up to 4 mg l^{-1} in all the cultivars in comparison to control but decreasing grain weight was observed insignificant at both the higher doses of As^V supply (8 & 12 mg l^{-1}) except IET 4786 (Satabdi) where decreasing in grain weight was significant with increasing supply of As^V. In general, As^V toxicity had led to early flowering in all selected rice cultivars consequently early seed maturity.

Supply of As^V at low concentrations promoted yield by enhancing nutrient availability such as P [9] and N_2 as observed by increase in number of tillers and seed weight. Growth stimulation at low application of As^V has also been reported [10] while As hyperaccumulator *Pteris vittata* showed increased growth upto 100 mg kg^{-1} soil As^V application [11]. In the present study, 12 mg l^{-1} As^V application retarded the growth and yield of rice cultivars as reflected by reduced plant height, number of tillers and seed weight, possibly due to retardation of chlorophyll contents as observed in the present study and also reported in oat [12,13]. Arsenic may inhibit chlorophyll

Table 1: Physico-chemical properties and metal composition of control pot soil and after supply of different As^V concentrations. All the values are mean of triplicates ±S.D. ANOVA significant at $p\leq0.01$. Different letters indicate significantly different values at a particular treatment (DMRT, $p\leq0.05$).

Parameters	Control	As (4 mg l^{-1})	As (8 mg l^{-1})	As (12 mg l^{-1})
pH	7.60^{α} ±0.32	7.40^{α} ±0.76	7.30^{α} ±0.54	7.00^{α} ±0.44
Electrical conductivity (Ω)	176.70^{γ}±5.66	275.30^{β}±8.21	283.00^{β}±8.88	332.30^{α}±9.21
Total organic carbon (%)	2.21^{α} ±0.05	2.46^{α} ±0.04	2.23^{α} ±0.04	2.30^{α} ±0.02
Water holding capacity (%)	71.98^{α} ±3.5	74.79^{α} ±4.9	75.62^{α} ±4.1	76.54^{α} ±5.1
Bulk density (g cm^{-3})	1.26^{α} ±0.04	1.20^{α} ±0.04	1.21^{α} ±0.03	1.18^{α} ±0.05
Particle density (g cm^{-3})	1.68^{α} ±0.01	1.72^{α} ±0.03	1.81^{α} ±0.02	1.79^{α} ±0.04
Available nitrogen (%)	0.49^{γ} ±0.01	1.18^{α} ±0.03	0.81^{β} ±0.02	0.90^{β} ±0.01
Metals (mg kg^{-1})				
Available phosphorus	447.42^{δ} ±11.3	725.69^{α} ±17.0	605.56^{β} ±27.20	525.47^{γ} ±16.66
Fe	76146^{α} ±336.3	75436^{α} ±300.9	76429^{α} ±26	73214^{α} ±299.50
Zn	221^{α} ±15.53	289.5^{α} ±24.79	263.83^{α} ±34.49	260.67^{α} ±21.89
As	5.43^{γ} ±0.23	24.00^{β} ±1.67	26.27^{β} ±1.21	31.17^{α} ±2.81
S	3.18^{α} ±0.12	3.48^{α} ±0.17	3.66^{α} ±0.19	3.21^{α} ±0.20

Citation: Bag MK, Adhikari B, Dwivedi S, Tripathi RD. Consequences of Arsenate Exposure on Important Yield-Associated Traits of Rice (Oryza *Sativa L.*). J Plant Sci Res. 2014;1(2): 109.

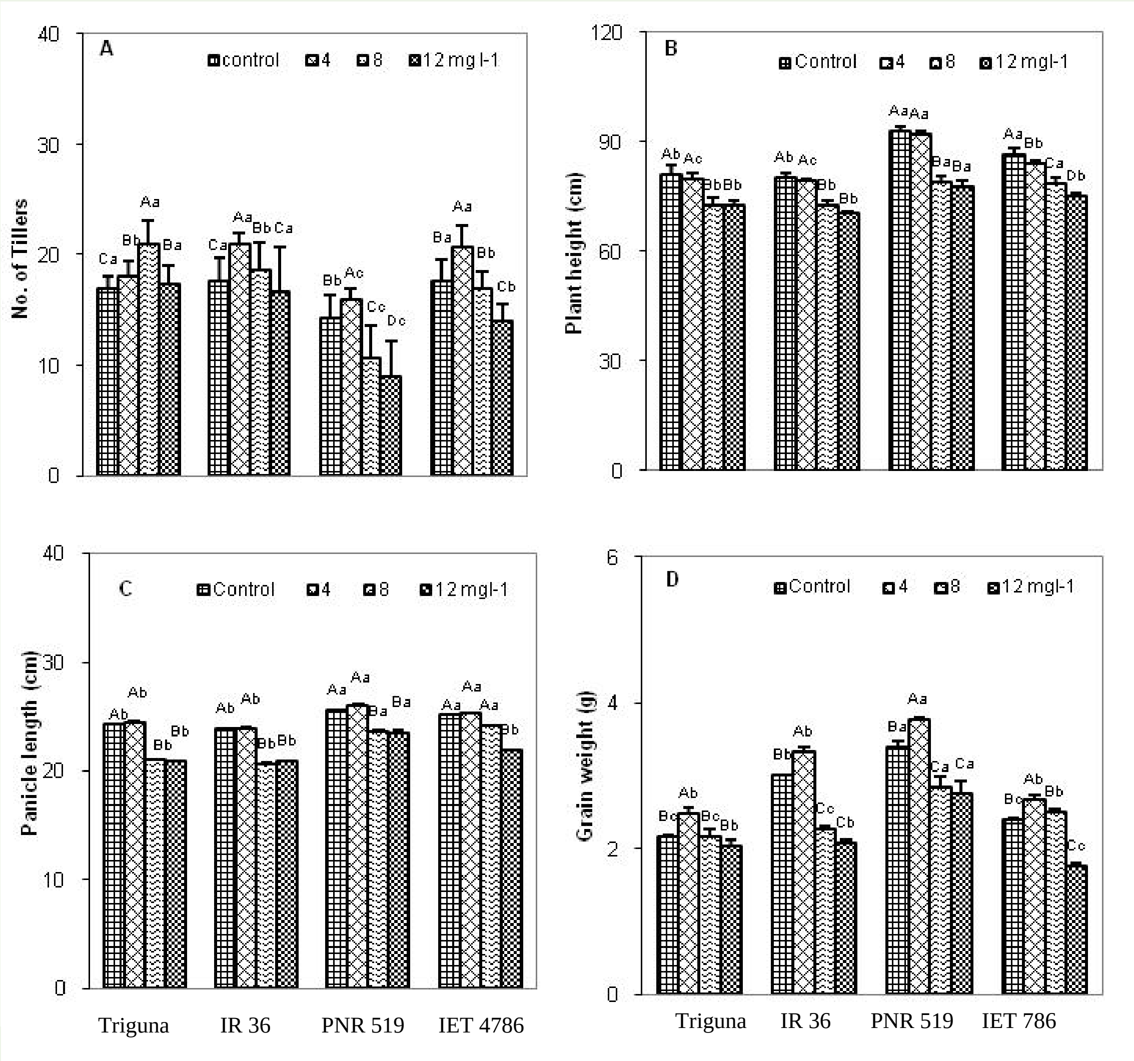

Figure 1: Effect of As^V on number of tillers (A); plant height (B); panicle length (C); grain weight (D) in different rice cultivars. All values are mean of triplicates ±S.D. ANOVA significant at *p≤0.01*. Different capital letters indicate significantly different values among As treatments in a particular rice cultivar and small letters indicate significantly different values among rice cultivars at a particular treatment (DMRT, *p≤0.05*).

biosynthesis by interfering the activity of δ-ALAD in greening maize leaf segments under As^V stress [13]. Further, application of As^V at lower dose enhanced accumulation of other nutrients (Fe, P, Zn and S) however, higher dose limits nutrient uptake in rice [14]. Higher As^V concentrations, hampered uptake of essential nutrients such as Fe, Mn, Cu, Zn etc. may also be a reason for inhibition of photosynthetic pigments, reduced growth and number of tillers [15].

Therefore, higher dose of As^V limits rice plant from nutrients uptake which attributes negative effect on plant growth and thus reducing the yield of rice grains.

Acknowledgement

We are grateful to the Director of Agriculture, Government of West Bengal, the Director of National Botanical Research Institute, Lucknow and Joint Director of Agriculture (Rice Development.), Rice Research Station, Chinsurah, West Bengal for their keen interest in the subject and providing full support to conduct the experiment.

References

1. Guha Mazumdar DN (2003) Chronic arsenic toxicity: clinical features, epidemiology and treatment: experience in West Bengal. J Environ Sci Healt. 38: 141-163.
2. Abedin MJ, Feidmann J, Meharg A A (2002) Uptake kinetics of arsenic species in rice plants. Plant PhysiolZZ128: 1120-1128.
3. Meharg AA , Rahman MM (2003) Arsenic contamination of Bangladesh paddy field soils: implications for rice contribution to arsenic consumption. Environ Sci Technol 37: 229-234.
4. Zavala YJ, Duxbury JM (2008) Arsenic in rice: Estimating normal levels of total arsenic in rice Grains. Environ Sci Technol 42: 3856-3860.
5. Williams PN, Price AH, Raab A, Hossain SA, Feldmann J, et al. (2005) Variation in arsenic speciation and concentration in paddy rice related to dietary exposure. Environ Sci Technol 39: 5531-5540.

6. Mokgalaka-Matlala NS, Flores-Tavizon E, Castillo-Michel H, Peralta-Videa JR, Gardea-Torresdey JL (2008) Toxicity of arsenic (III) and (V) on plant growth, element uptake, and total amylolytic activity of mesquite (*Prosopsis juliflora x P. velutina*). Int Phytoremediation 10: 47-60.

7. Dwivedi S, Tripathi RD, Srivastava S, Singh R, Kumar Amit, et al. (2010) Arsenic affects mineral nutrients in grains of various Indian rice (*Oryza sativa* L.) genotypes grown under arsenic-contaminated soils of West Bengal. Protoplasma 245: 113-124.

8. Gomez KA, Gomez AA (1984) Statistical procedures for agricultural research. John Wiley, New York.

9. Adhikari B, Bag MK, Tripathi RD (2011) Effect of arsenate on phosphorus accumulation in rice under simulated condition. Journal of Crop and Weed 7: 8-11.

10. Srivastava S, Mishra S, Tripathi RD, Dwivedi S, Trivedi PK, et al. (2007) Phytochelatins and antioxidants systems respond differentially during Arsenite and Arsenate stress in *Hydrilla verticillata* (L.f.) Royle. Environ Sci Technol 41: 2930-2936.

11. Tu C, Ma LQ (2005) Effect of arsenic on concentration and distribution of nutrients in the fronds of the arsenic hyperaccumulator *Pteris vittata* L. Environ Pollut 135: 333-340.

12. Stoeva N and Bineva T (2003) Oxidative changes and photosynthesis in Oat plants grown in As-contaminated soil. Bulg J Plant Physiol 29: 87-95.

13. Jain M, Gadre R (1997) Effect of As on chlorophyll and protein contents and enzyme activities in greening maize tissues. Water Air Soil Pollution 93:109-115.

14. Dwivedi S, Tripathi RD, Tripathi P, Kumar A, Dave R, et al. (2010) Effects of arsenate exposure on amino acids, mineral nutrient status and antioxidant in rice (*Oryza sativa* L.) genotypes. Environ Sci Technol 44: 9542-9549.

15. Williams PN, Islam S, Islam R, Jahiruddin M, Adomako E, et al. (2009) Arsenic limits trace mineral nutrition (selenium, zinc and nickel) in Bangladesh rice grain. Environ Sci Technol 43: 8430-8436.

Citation: Bag MK, Adhikari B, Dwivedi S, Tripathi RD. Consequences of Arsenate Exposure on Important Yield-Associated Traits of Rice (Oryza *Sativa L.*). J Plant Sci Res. 2014;1(2): 109.