Alleviation of altered ultrastructure in arsenic stressed rice cultivars under proposed irrigation practice in Bengal Delta Basin

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ABSTRACT: Application of a periodical intermittent water cycle during rice cultivation proved its potential for minimizing considerable bioavailability of arsenic (As) in soil. We also propose two parametric equations, determining arsenic release from seasonal field conditions. Soil samples were determined through Raman spectroscopy and ICP-MS. The practice also alleviate stress from ultra-physiological xylem-phloem integrity of plant parts compared to conventional flooded cultivation, as observed under FE-SEM. Rice grains were analyzed for As concentrations using Synchrotron-XRF for two rice cultivar with subsequent internal and external surface topography determination under AFM showing greater amplitude of roughness in As stressed grains from conventional cultivation. Fresh plants were analyzed for biomass with pigmentation and stress regulator enzymes viz. malondialdehyde (MDA), catalase (CAT), superoxide dismutase (SOD), guaiacol peroxidase (GPX) and total protein from both conditions and found to be better in proposed cultivation method with better sustainable productivity. Isolated rhizospheric bacteria also plays crucially in arsenic uptake and metabolism.

1 INTRODUCTION

Arsenic hazards in South-East Asia compromises socio-economic and health perspective of millions of peoples (Meharg, 2004). Arsenic contamination to the groundwater and thereafter to the rice grain needs a sustainable restriction approach and scientific communities around the globe are trying to minimise this natural poison to get entered in the food chain. Rice plant can take up As more efficiently compared to other cereals (Williams *et al.*, 2007) which is why agro-nomic practices and soil physico-chemical parameters plays crucially in arsenic mobility (Barla *et al.*, 2017). Accumulation of arsenic can severely damage internal plant cell organelles and altered vesicles (Li *et al.*, 2006) with releasing high amount of reactive oxygenic species (ROS) resulting in elevation of stress regulating enzymes (Shri *et al.*, 2009). Rhizospheric microbes on the other hand ensures some partial bio-rendering of As changing redox status and being transported to the rice root system covered with iron plaques (Zecchin *et al.*, 2017).

2 EXPERIMENTAL

2.1 Soil-groundwater sampling and assessment

Samples were collected from two different experimental fields, intermittent flooded (IF) and conventional flooded (CF), a part of Nadia district, West Bengal, India. Both the samples were analysed by both ICP-MS (acid digested) and Raman Spectroscopy (untreated) for arsenic and other element determination.

2.2 Plant arsenic determination

Rice plants were sampled, segmented and finely chopped to make pallets for assessment under synchrotron X-ray fluorescence (Indus-2 beamline, India) for elemental analysis with subsequent rice grain internal and external surface topography determination by atomic force microscope (AFM) to check the physiological effect of As on rice grain. Leaf and nodal xylem-phloem integrity were also observed under field emission scanning electron microscope (FE-SEM).

2.3 ROS scavenging enzymes

Fresh plant tissues were measured for the production of anti-stress regulator enzymes. Comparison between IF field plant's biomass, total protein, pigment content and CF field plants were made.

2.4 Microbial amendments

Arsenic resistant Fe oxidizing-reducing bacteria were isolated and screened for the highest As tolerance level subsequently applied in soil As restriction.

3 RESULTS AND DISCUSSIONS

3.1 Arsenic contentment

Both soil and rice grains contains arsenic beyond permissible limit by WHO-FAO (2016) due to continuous application of As rich groundwater in CF field whereas

Figure 1. Arsenic in samples from two different irrigation practices.

Figure 2. Ultrastructure comparison in rice.

in IF field, the As load in rice grain is much less and ensures to be lesser in subsequent practice (Figure 1). The average concentration of As in selected area lies within $75\text{--}90\text{ }\mu\text{g L}^{-1}$.

Graphical representations are showing As concentrations in groundwater, soil and rice grains in consecutive 2016 and 2017 samples as a mean of triplicated data. Green line indicates permissible limit of As in rice grains. Application of IF system involves redox change and decreased bioavailability (BA) of As resulting in lesser As in rice grains.

3.2 Alleviated ultrastructure

Translocation of As proceeds through vesicular network that gets structurally distorted in the presence of high ROS content. Reduced BA affects less to the internal vesicular organelles like xylem (X), phloem (P) and bundle sheath (Bs) in IF compared to CF as shown in Figure 2.

3.3 Variation in ROS scavenging enzymes

Fresh plants from the CF field showed much higher production of MDA, CAT, SOD and GPX compared to IF field plants, indicating a greater extent of As phyto-accumulation in CF plants (Figure 2). This causes an internal degenerative stress molecules triggering ROS scavenging enzymes in CF plants.

3.4 Microbial enhancement

Isolated bacterial species can tolerate up to 400 mg kg^{-1} of arsenite and 1000 mg kg^{-1} of lead concentrations with 30% of that are being bioaccumulated within the cells itself. This proved to be a fascinating bioremediation agent with some potential nutritional enrichments.

Figure 3. Stress responsive enzymes in rice plant. Data are the mean of triplicated values.

4 CONCLUSION

Implementation of intermittent dry-wet irrigation over the conventional flooded practice amended with bio-restrictors makes internally healthier and As-less rice with low risk of health hazards.

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