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Characterizing Soil Induced Variation of Arsenic Uptake in Rice

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Abstract—*Arsenic contamination in ground water and their effect on soil-plant-anima land humans have been reported from various parts of the world. Rice is the dietary staple our world has greater prospect to grow and exploit as it is typically grown up under waterlogged condition favoring arsenic mobilization than any other crop like wheat barley or maize. Arsenic contamination of shallow ground water and related health problems are threats for millions in endemic regions of West Bengal. The genetics of arsenic uptake and accumulation has been very less studied in plants as compared to animals and human being. Naturally occurring resistance to high soil arsenic, has been observed in some species, which has shown to be caused by the reduction of phosphate as well as arsenate uptake. The persistence of heavy metals in the environment may pollute or contaminate soils and aqueous streams as both natural components are the result of human activity. Amongst the various heavy metal contaminants arsenic and lead are recognized as the leading toxicants worldwide from these experiment results I could conclude that out of the 4 varieties I took for my experiment 4786 is the best arsenic resistant variety but here only few farmers are using it as because of price and also they are unaware about the arsenic resistant properties and good qualities of the variety. If proper varieties are used then we can easily increase production of arsenic less paddy, and if even a 10 % reduction of arsenic in rice grain could happen then we can save hundreds of thousands or even millions of lives. As we know Arsenic contamination of shallow ground water and related health problems are threats for millions in endemic regions.*

1. INTRODUCTION

Rice is very important as being an irreplaceable source of major food supply is predominantly cultivated through wetland production system. The genus Oryza contains about 23 wild species, grown in 114 countries under about 171 million ha. Nearly 90%of the world's rice is produced and consumed in Asia. The primary center of origin of cultivated rice may be south east Himalaya. Archeological evidence suggests that rice is originated 5000 BC at Hemudusite in Taifu area of eastern China. Rice spread in the Europe particularly in Greece and Mediterranean region during 344-324BCby Alexander then further in southern Europe and north Africa. In India rice is the staple food crop and is grown on 42.5m ha, largest among rice growing country in area Rice is a source of directly consumed calories for about half the world's population. Millions of humans are at risk of arsenic poisoning caused due to drinking of arsenic contaminated water and food. Arsenic causes serious health problems in animals, humans and plants. Worldwide Rice is one of the basic crop known for its high potential to accumulate heavy metals and arsenic caused due to anaerobic cultivation. Boro rice which is grown using ground water is significant source of arsenic. The objective of my research is to develop a low arsenic accumulating variety by breeding methods. For this, 250 rice genotypes including few photo-insensitive varieties were analyzed for arsenic accumulation ability in straw and grain (with and without hull). It was observed that straw accumulate significantly higher amount of arsenic than grain, but linear correlation did not exist among straw and grain accumulation. The effect of arsenate with or without phosphate on the growth and metabolism of rice seedling was also studied for cultivar - i) Nayanmoni, ii) GB1, iii) 4086 and iv) 4094. In most of the varieties arsenic was more toxic in root growth than the shoot growth where root hairs were fewer and short, stubby, brittle and root tips gradually turn brown. As arsenic caused damaged to the root epidermal cells and parenchymatous cortex. Joint application of phosphate with fertilizer showed significant alteration of all parameters tested under the preview of arsenic treatment alone leading to better growth and metabolism. Thus the use of phosphate enriched fertilizer in arsenic contaminated soil may improve the production of arsenic less healthy rice plant.

2. RICE SPECIES INFORMATION

- Scientific name: Oryza sativa L.
- Common name: rice, paddy rice, chowdhury rice (English); dhanya, vrihi, nivara, syali (Sanskrit); dhan, chaval (Hindu); chal (Bengal); dangar choka (Gujarat); nellu, arisi (Tamil). Taxonomy
- Class: Equisetopsida
- Subclass: Magnoliidae

- Superorder: Lilianae
- Order: Poales
- Family: Poaceae
- Genus: Oryza

World rice production in 2014/2015 was 476.36 million tons. While it is 475.04 (estimated) million tons in 2015/2016 which represent a decrease of 1.32 million tons or a 0.28% in rice production in globe. (SOURCE AMERICAN NEWSPAPERS) it is a matter of concern and we should mitigate the different causes of reduction in production, and very important cause is due to availability of arsenic in rice

USES OF RICE-ORYZA SATIVA

- Rice starch mixed with honey to nourish the skin and can be used in cosmetics to reduce facial 'shine'.
- The rice oil --- conditioners for hair-care and in shower and shampoo products moisturising and anti-ageing properties.
- Rice Extracts containing rice protein are added to hair products to give a feeling of volume and thickness to the hair.
- The husks and grains of rice are used as bedding for mushroom growing medium, organic manure and a mulch, fuels and building board.
- Rice straw is used for animal feed and bedding, and can be made into paper and board pulp.
- Bran oil is used in cooking, and has anti-corrosive properties. It is also used as a textile and leather finisher. Rice bran contain 25% fibre, which absorb fats. Decreases levels of cholesterol in the blood, aids digestion and can be used as a mild laxative.
- Sticky glutinous rice to treat stomach upsets, heart-burn and indigestion.
- Extracts from brown rice to treat breast and stomach cancer, warts indigestion, nausea and diarrhoea.

PROPERTIES OF ARSENIC

Discovered: 2500 BC

Symbol: As

Electron configuration: [Ar] 4s2 3d10 4p3

Melting point: 816.85 °C

Boiling point: 613 °C

Atomic number: 33

Arsenic is a metalloid - a natural element that has both properties of metal and nonmetal. It is a natural component of the Earth's crust, generally found in trace quantities in all rock, soil, water and air. However, concentrations may be higher in certain areas due to either natural conditions or human activities. Soil contaminants - organic like petroleum, hydro-carbon, fertilizer, pesticide, copper, nickel cobalt zinc, Inorganic like arsenic cadmium, mercury, lead. According to (WHO), total daily intake should not exceed 2 mg of inorganic arsenic per kilogram of body weight. High proportion of arsenic inhibition of seed germination decrease plant height reduction root growth, leaf area photosynthesis and low grain yield. Acute arsenic intoxication muscular pain weakness with flicking skin severe nausea and vomiting colicky abdominal pain profuse diarrhea with rice-water stools. Capillary damage transudation of fluid in the bowel lumen numbness in hands and feet reddish rashes in the body intense thirst. In severe poisoning skin becomes cold and clammy circulatory collapse kidney damage decreased urine output. Some of the Arsenic are useful also for wood and leather preservation, polishing and medicinal purposes

3. METHODOLOGY

The goal of my work is to find method of reduction of arsenic content in rice Either by making arsenic ineffective, not allowing them to enter the grain and plant as a whole or by removing them. To Compare arsenic content and other physical and chemical properties of soil for Nadia district of West Bengal.

Experiment was done by taking four varieties of paddy which are predominantly used by local farmers of the Chakdha district of West Bengal, collected from B.C.K.V.V. SEED FARM at Chakdha. Survey was done to isolate mostly used arsenic resistant variety by the local farmers, by going to the selected 24 farmers under study, information was taken why and which variety they are planting. Comparison was done among the 4 varieties for Arsenic content in different plant parts of all the varieties, and the best varieties were scrutinized. Comparison was also done for the physical and chemical properties of soil collected from 24 farmers selected for the study. Study on arsenic related to germination vigor viability and productivity of rice genotypes and its invigoration by physiochemical treatment was done with different chemicals. Follows are the experiments done in the field and in the lab for Isolation of suitable arsenic resistant rice variety for Nadia district environment.

1. One replicate beaker containing 15-20 seedlings at six concentrations of arsenic was used to characterize the dose response, the data for each plant in a beaker was averaged and the standard error was calculated.
2. The response of 20 rice varieties to 13.3 μM arsenate was tested. In order to estimate source of variation two rreplicate beakers each containing 10 plants was used for both control and treatment. The vast majority of variance between individual plants in beakers, rather than between beakers was studied by comparing 40 pair-wise beaker

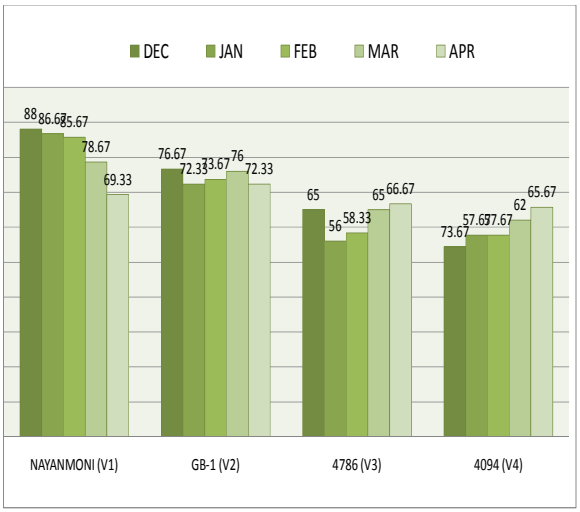
3. The variance was confirmed by three-way analysis of variance (factors: genotype, treatment and replicate beaker) and its interaction with the other factors was an order of magnitude lower than the error variance calculated by dividing its root length by the average root length of all 20 control plants.
4. To test arsenate tolerance, seeds were allowed to germinate in the lab for 3 days at 37°C and then floated on alkathene beads within 250 ml beakers filled with phosphate-free nutrient solution
5. The seedlings was grown in controlled conditions at 25°C with a 12 hour/day length. After 1 wk the maximum length of the root of plants was measured. The tolerance index was calculated as the percentage of root length in arsenate compared to the control.
6. The distribution of tolerance was indicated in two discrete classes, and a value of > 40% was taken to indicate tolerance, and < 40% to indicate sensitivity to arsenate to allow the tolerance reaction to be treated as a genetic marker. The arsenate tolerance gene was placed on the map using Map Maker 3.0 (Lander *et al* ., 1987; Lincoln *et al*, 1992) with the Haldane algorithm.

4. RESULTS AND DISCUSSION

Isolation of arsenic resistant variety for Nadia District Comparison of arsenic content on different variety produced. For this experiment soil sample were collected from 24 farmers field of Chakdha, of Nadia district of West Bengal and seed research farm of B.C.K.V. comparison of seed quality by germination test in the field and in the lab was done and agronomy characters were measured and compared. Germination test were done in laboratory in the Petridis. 100 Seeds were allowed to grow with distilled water. Readings for Agronomical characters were taken after nine days, for finding out which variety is best. The experiment was repeated every month to see how germination % increases or decreases. The results of different tests undertaken were more interesting as we found some varieties are very resistant and some are very susceptible to Arsenic uptake. The following graphs figures and tables showed results

Table 1

The varieties I took are prominent in Chakdha district and farmers are growing without any knowledge about the variety. From these experiment results I could conclude that out of the 4 varieties I took for my experiment Variety 4786 is the best arsenic resistant variety.



The two varieties Nayanmoni and GB1 showed above 80 % during December which decreases slowly up to 75%. So this two varieties are very good as their germination% is high which lasts for 4 months. other two varieties 4049 and 4786 showed germination % 50 – 55 which slowly increases up to 65%. Out of these two variety I recommend 4786 as it shows good germination less arsenic content and can last viable for a longer period and farmers can use these two varieties as late variety.

DEC-SEED GERMINATION (CRITICAL DIFFERENCE= 5.212189)
JAN-SEED GERMINATION (CRITICAL DIFFERENCE= 2.684688)
FEB-SEED GERMINATION (CRITICAL DIFFERENCE= 1.73029)
MAR-SEED GERMINATION (CRITICAL DIFFERENCE =3.601886)
APR-SEED GERMINATION (CRITICAL DIFFERENCE= 2.60077)

Table 2

Isolation of suitable arsenic resistant variety for Nadia District
The experiment was done in the lab for seed collected from seed farm Nadia and compared with the control

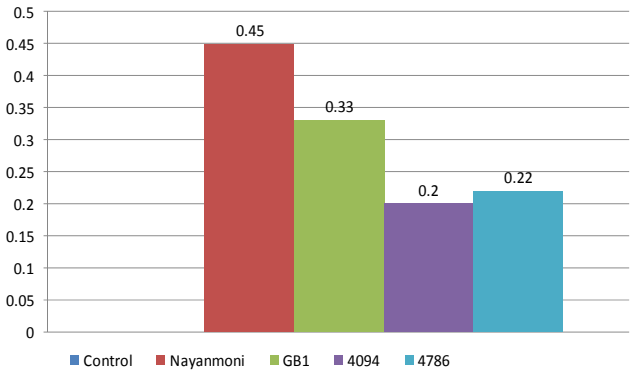


Table 3

Comparison of arsenic content and other physical chemical characters of soil for Nadia district of West Bengal

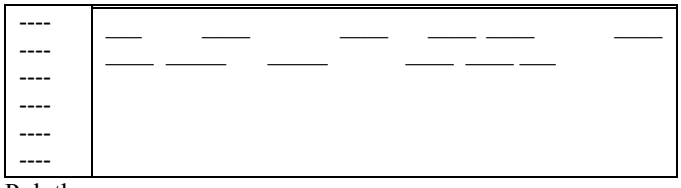
	Name	Village	Dist	Dag No	Arsenic	Mineral & Salt	PH	Live Carbon%	Acceptable Phosphates	Acceptable Potassium
1	Haran Chandra Das	Phetugachi	Nadia	Jodkhambba	.3171	0.16	8.14	High	Low	Low
2	Narayan C Das	Phetugachi	Nadia	Uparer Phali	.3178	0.13	8.18	Low	Medium	Low
3	Badsha Mondal	Sajerdhar	Nadia	Sajerdhar	.3166	0.11	8.07	Low	Low	Low
4	Badsha Mondal	Chasadhopapara	Nadia	Sajerdhar	.3174	0.14	8.14	low	Low	Low
5	KRISHNA GOPAL DAS	MOHISH DANGA	Nadia	PURBODIPER PHALI	.3175	0.19	8.22	Low	Low	Low
6	KRISHNA GOPAL DAS	MOHISH DANGA	Nadia	PASCHIM DIPER MOMI	.3168	0.12	8.2	Low	Low	Low
7	MADHAV DAS	MOHISH DANGA	Nadia	DHIJAN DASER	.3173	0.1	8.24	MEDIUM	Medium	Low
8	MADHAV DAS	MOHISH DANGA	Nadia	16 SATAK	.3165	0.13	8.31	MEDIUM	Medium	Low
9	MADHAV DAS	MOHISH DANGA	Nadia	ACHEYDER JAMIN	.3179	0.18	8.15	Low	Medium	Low
10	MADHAV DAS	MOHISH DANGA	Nadia	BIRENDASER	.3176	0.14	8.13	Low	Medium	Low
11	ABER ALI MONDAL	JATRAPUR	Nadia	BOROFALI	.3159	0.16	8.05	Low	Medium	Low
12	LUTKAR MONDAL	NARAPOTIPARA	Nadia	NH34	.3161	0.18	8.25	Low	Medium	Low
13	YAKUB MONDAL	MOLLAPARA	Nadia	CHOUKA PHALI	.3164	0.17	8.1	Low	Medium	Low
14	POLASH BURMAN	SIMIRALI	Nadia	JOLEDHAR	.3167	0.14	8.17	Low	Medium	Low
15	SUBROTO SARKAR	SIMIRALI	Nadia	BOROFALI	.3169	0.15	8.2	Low	Medium	Low
16	BACHU SANTRA	GONTRA	Nadia	BOROPUKURERDHAR	.3177	0.17	8.2	Low	Medium	Low
17	NARAYAN GHOSH	MONDALHAT	Nadia	SEGURTALA	.3180	0.15	8	MEDIUM	Medium	Low
18	KASSENG MONDAL	MONDALHAT	Nadia	YEDOPUKUR	.3172	0.19	8.17	MEDIUM	Medium	Low
19	ACHIR MONDAL	TELULBERE	Nadia	LONARBIR	.3170	0.12	8.13	MEDIUM	Low	Low
20	HOSEN MONDAL	DEREPARA	Nadia	OUSERSETU	.3160	0.14	Jan-00	Low	Low	Low
21	ABURSADUKHA	JAGULI	Nadia	AGERJAMIN	.3162	0.11	8.24	Low	Low	Low
22	SERAJ MALLIK	NATUPALLI	Nadia	RASTEDHARE	.3163	0.15	8.06	Low	Low	Low
23	1 NGO	GOINTRA	Nadia	CHAKDHA	.2808	0.12	Jan-00	Low	Low	Low
24	2 NGO	GOINTRA	Nadia	CHAKDHA	.2807	0.16	8.01	MEDIUM	Medium	Low

Soil sample are collected from three different points of soil surface (0-20 cm) from the 24 farmers field at Chakdha, it was sundried passed through 2mm sieve and used for physical chemical and microbial analysis. Soil sample tested for arsenic ph, nitrogen, phosphorus and potassium

Table---4

A total of 4 rice varieties were obtained from the International Rice Research Institute (IRRI) Bhubaneswar, local seed research farm of B.C.K.V.V. These include parents of several rice mapping populations. The seeds were stored in deep freeze and used accordingly. When required Seeds were grown on the raised nursery beds which were prepared with vermin-compost, FYM and soils above the plastic

RAISED NURSERY



Polythene

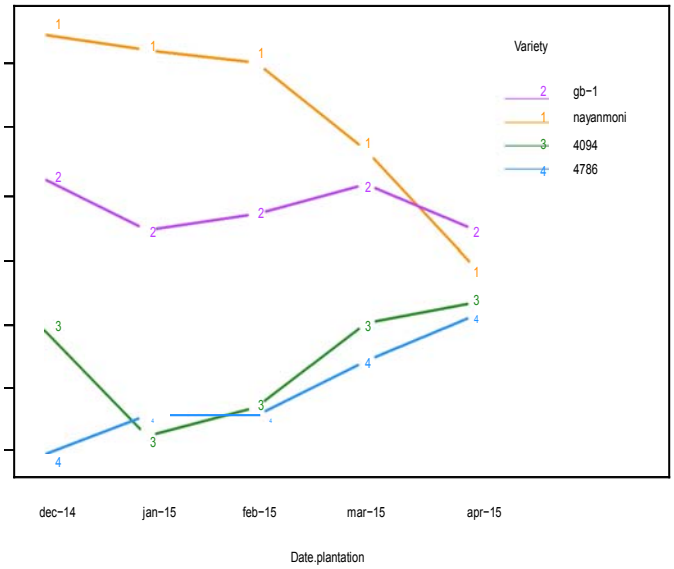
FYM/ Vermi-Compost + Soil

4 – 6 ‘’ Raised

2 Kg seed/acre

Table 5

COMPARISON OF FOUR VARIETIES FOR ARSENIC CONTENT IN DIFFERENT PLANT PARTS EXPERIMENTS WERE CARRIED OUT IN THE FIELD UP



Computational simplification

Time point –factor

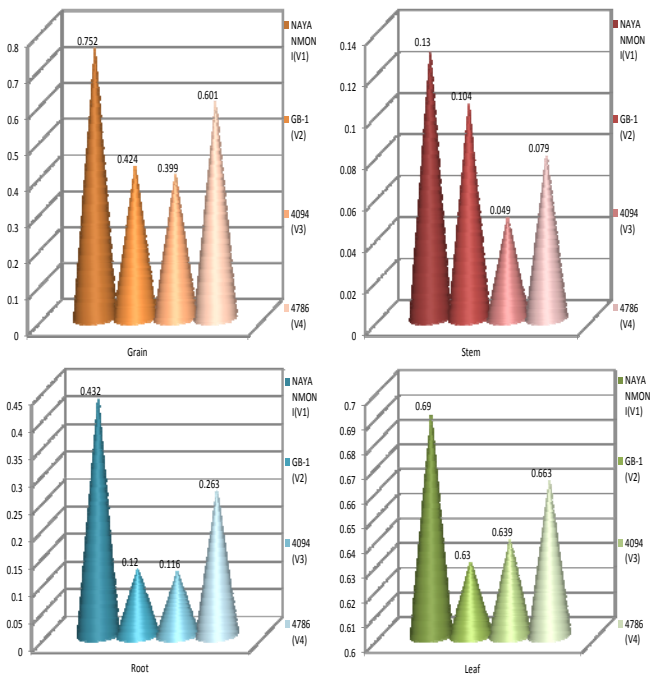
1. Affected by climate

2. Germination by variety collected

Problem of analysis of two-way classified data.

Table 6

Measurement of arsenic content shows that lowest is found in grain v2 .399 and v3 .424 in root v3.11and v2.12 in stem v3 .049 and v4.079 in leaf, v2.53 and v3 .63.so overall v3 has minimum AS content



Arsenic value for grain of four different varieties were measured and compared with the control and found that Nayanmoni has the highest Arsenic content while 4094 has the lowest Arsenic content. So I recommend 4094 as the best arsenic tolerant variety out of the four for the Nadia district of West Bengal INDIA. But overall the best variety is 4786. So farmers should be informed about this result and asked to use these varieties with SRI method of cultivation as this method of rice growing is ecologically and economically favorable as compared with lowland submerged cultivation methods.

The aim of this article is to give an overview of the arsenic contaminant in soil and rice plant and also the mechanism of mitigation of these toxic metals by different method. From my experiments results it can be concluded that SRI cultivation technique produces quality rice grain and more important this method of rice growing is ecologically and economically favorable as compared with lowland submerged cultivation methods. The fact that even a 10% reduction in rice grain arsenic content could save thousands of lives. So, now the real challenge in front of us today is perhaps to develop/ adopt strategies based on ecological principles and integrating traditional farming practices and biodiversity with scientific knowledge to solve this big problem.

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