Screening Of Rice Cultivars For Grain Arsenic Speciation And Concentration

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INTRODUCTION

Why should grain As levels be decreased?

Arsenic (As) levels in rice (*Oryza sativa L.)* are a concern for some South Asian countries with very high As concentrations in drinking water or to the populations consuming rice as a staple food. Rice plants are reported to contain organic As compounds namely MMA (monomethyl arsonic acid) and DMA (dimethyl arsenic acid) and inorganic As such as arsenate [As(V): $H_2AsO_4^{1-}$, $HAsO_4^{2-}$] and arsenite [As(III): $H_3AsO_3^{\circ}$]. Studies show that organic As is considerably less toxic and readily expelled from the body through urine whereas the inorganic forms of As have longer retention times in the body and can be of potential concern (Johnson and Farmer et al.,1990; Cohen et al., 2006). Therefore it is of interest to minimize additional As exposure by developing high quality rice with low As levels and higher organic to inorganic As ratios.

Does straighthead disorder result from higher As accumulation in grain?

The soils previously contaminated with the arsenical herbicide monosodium methylarsonate (MSMA) are sporadically susceptible to a rice physiological disorder called straighthead, which results in incomplete grain fill and decreased rice yields. For more than 10 years straighthead variability in cultivars has been successfully screened under continuous flooding following MSMA application to the soil. But straighthead symptoms reported world wide have indicated that high As in the soil is not an essential criteria, but prolonged flooding of paddy resulting in low soil oxygen levels is the common feature observed. It is not known whether the straighthead symptom of partial panicle sterility is associated with grain As concentration or As speciation.

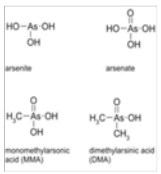

Figure 1. Arsenic species found in rice plants

Figure 2. Herbicide monosodium methylarsonate (MSMA) applied to soil at the rate of 6.7 kg/ha to induce straighthead

Figure 3. Straighthead disorder symptom in rice characterized by incomplete grain fill at maturity

OBJECTIVES

- To compare rice cultivars on a native soil tested for high As bioavailability and an MSMA - amended soil for the relative concentration of As in grain
- To evaluate the relationship between grain-As concentration and susceptibility to straighthead
- To compare selected cultivars for their inorganic versus organic As concentrations in grain

METHODS

A total of thirty-seven rice cultivars of subspecies indica and japonica with known and unknown susceptibility to straighthead were selected for growth in a replicated field trial at Stuttgart, AR. The two treatment soils were a native soil previously assessed as having a relatively high bioavailability of As and a conventional straighthead test plot amended with 6.7kg/ha MSMA before planting. The 4 replicated plots of each cultivar in each treatment had dimensions of 6x4 feet with 6 rows (1 ft apart).

Straighthead scores of 1-8 were assigned to rice cultivars based on the number of filled grains in the panicle, from the center of the plots as described by Yan et al. (2005).

Total As concentration in milled rice grain was determined by ICP-MS following digestion in HNO_3/H_2O_2.

Arsenic species were quantified from powdered grain using HPLC-ICP-MS following extraction with 1M TFA (Trifluoroacetic acid).

RESULTS & DISCUSSION

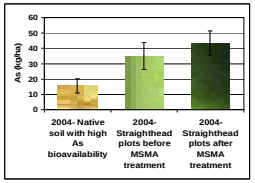

Figure 4. Soil As levels in the two soil types selected for rice growth

Figure 5. Cultivar Cocodrie in straighthead test plot with sterile and upright panicles

Figure 6. Cocodrie panicles weighed down by normal grain fill in native soil with no MSMA treatment

Figure 7. Cocodrie panicles in MSMA treated straighthead plots with upright panicles due to incomplete grain fill

- The soil As levels were very high in the straighthead testing plots because of MSMA application in past several years for screening rice.
- Straighthead rating and grains for As measurement were taken from the center most one foot length of two rows where soil was reduced the most and maximum straighthead susceptibility was found.
- No straighthead was observed in native soil plots with no applied MSMA due to sporadic nature of straighthead.

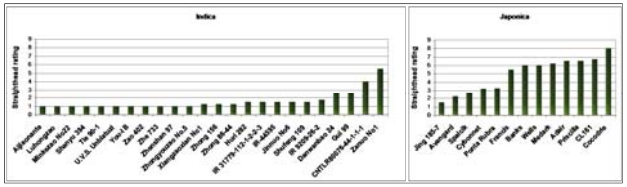

Figure 8. Straighthead rating for 37 indica and japonica cultivars in MSMA-treated plots in 2004 (presented in order of increasing straighthead rating).

- The MSMA treatment differentiated cultivars for straighthead tolerance ranging from complete grain fill (rated 1) to panicles with no grain fill (rated 8).
- In this sample set, the indica cultivars were on average less straighthead susceptible compared to the japonica cultivars. Increased straighthead susceptibility could result in increased yield loss under unfavorable conditions.

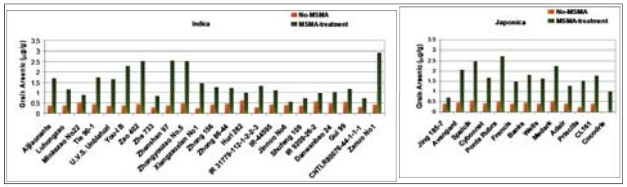

Figure 9. Grain As levels in 37 indica and japonica cultivars from MSMA-treated and untreated plots in 2004 (presented in increasing order of straighthead rating).

RESULTS & DISCUSSION

- Straighthead susceptibility does not appear to be related to grain As level. These two parameters are likely impacted by different genetically controlled plant processes.
- Some cultivars with relatively low grain As levels from native soil had relatively high levels with the MSMA treatment and vice versa, indicating that (i) different plant processes are likely involved in the absorption and transport of inorganic As and MSMA and (ii) different soil As species could be preferentially absorbed by different rice cultivars.
- In this sample set, several indica cultivars had lower grain as levels from the MSMA untreated native soil.

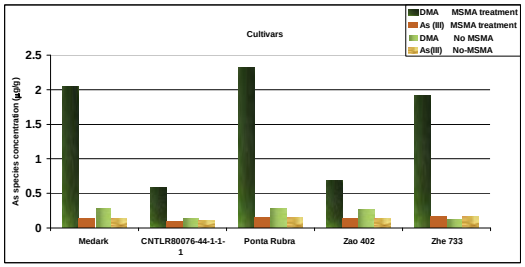

Figure 10. Grain As species in five cultivars from MSMA treated and non-treated native soil

- The inorganic As in grain was only detectable as As(III). The TFA extraction method generally converts As(V) to As(III), indicating the likelihood that inorganic As(V) from grain was transformed to As(III) within the extract.
- The inorganic As in grain was only detectable as As(III) following TFA extraction, indicating the likelihood that inorganic As(V) was transformed to As(III) within the plant.
- The As(III) levels in the grains from MSMA treated and non-treated plots were surprisingly very similar possibly indicating a minimum threshold limit of inorganic As in each cultivar.
- The increased As uptake from the MSMA treatment resulted in a significant increase of DMA in the grain.

RESEARCH SIGNIFICANCE

- The study demonstrated that straighthead susceptibility of a cultivar does not determine the As levels in the rice grain.
- Cultivars have been identified that show high tolerance to excessive As in the soil while maintaining relatively low As levels in the grain.
- As speciation analysis of selected cultivars revealed that excess As in the grain is stored in the form of less harmful organic As compounds.
- Rice cultivars with lower inorganic As levels in grain will be useful for populations consuming high inorganic As levels through water and food.

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