How management practices influence Fe plaque mineral composition and As cycling in rice paddies

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Rice, a staple food for half of the global population, is threatened by arsenic (As). The uptake and grain storage of As in rice decreases yield and impacts human health upon chronic consumption of As-laden grain. There is thus a critical need to not only grow more rice, but to ensure that the grain produced is safe for global food security.

As phytoavailability to rice roots depends on the local soil conditions, i.e., management strategies. Upland rice has low As phytoavailability due to high affinity of As for soil solids inclusive of Fe (III) (oxy)hydroxides under oxidizing soil conditions. In contrast, the phytoavailability of As is relatively high in paddy rice where reducing soil conditions lead to the reductive dissolution of Fe (III) (oxy)hydroxides and As release, and also in paddy fields irrigated with contaminated water. The extent of root-uptake of As under flooded conditions depends on how effective plant roots, associated microorganisms, and competing solutes are at attenuating As uptake. Rhizospheric oxygenation potentially limits As uptake via microbially-mediated or abiotic oxidation of Fe (II) at or near the root, forming a mixed-phase Fe (III) oxyhydroxide plaque. The mineral composition of Fe plaque influences As sorption and is affected by solutes, particularly organic matter and silicon (Si). Silicon also plays a large role in arsenite phytoavailabilty through direct competition for sorption onto mineral surfaces and uptake by rice roots.

Here, we discuss the interplay of plant-mineral and plant-microbe interactions on As accumulation in rice under different management scenarios. We show that strategies to increase phytoavailable Si in soil alter Fe plaque mineral composition and are effective at decreasing inorganic grain As by up to 50% and significantly improving yield, the latter particularly effective when plants are challenged with excess As in irrigation waters. In contrast, strategies utilizing water management decrease grain As but compromise yield and increase grain cadmium (Cd). Soil Si management may be an effective tool to increase rice quantity and decrease grain As.