Silicon and Lime as Soil Amendments for Rice to Reduce Arsenic Levels in Grain

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The objective of this project is to evaluate silicate fertilizer and lime for reducing arsenic in rice. Consumer Reports magazine published a story in November 2012 showing arsenic levels from 66 rice brands purchased in stores in New York City and on-line (1). Total arsenic in most rice was several times higher than the EPA allowable levels in drinking water, 10 ppb. Television shows such as The Doctors and Dr. Oz picked up on the story. Within brands of rice tested, brown rice was higher in arsenic, As, than milled white rice because the bran contains most of the nutrients in the grain. Inorganic arsenic is a carcinogen which has been linked to bladder and lung cancer. Ironically, Asian people who eat rice three times per day have the lowest incidence of these types of cancers.

Arsenic and silicon, Si, react almost the same in soil. In drained fields, arsenate, As [V], and silica ions are adsorbed on oxidized iron particles. When fields are flooded for rice, ferric iron +3 is reduced to the ferrous form +2 releasing As and Si into solution where they can be taken up by rice roots (2). Recent research showed that As in rice grain was reduced by applying soluble silica fertilizer. Si competes with As ions for root entry points (3). Liming can help depending on what species of As is present. Raising soil pH decreases arsenate adsorption by iron but increases arsenite, As[III], adsorption (4). Lime and calcium silicate from steel mill slag reduced As in radishes grown in contaminated soil (5).

Silicon is good for rice yields and arsenic is bad. Tissue Si and As content are usually higher in rice than crops such as corn and wheat. In rice, Si promotes disease resistance and helps plants withstand stresses such as salinity and dry soil (6, 7). Conversely, arsenic in rice tissue reduces yield by producing panicles without grain called straight heads. Breeders are working to identify varieties with lower As content in grain, but fungal diseases may increase due to lower tissue Si. Molecules of arsenite, 4.11 angstroms, and silica, 4.38, are similar in diameter and shape. Since arsenite is slightly smaller, blocking As from passing through root membranes to the xylem also inhibits Si uptake (8). Two proven methods to significantly reduce As in rice grain are silica fertilization and growing rice without flooding (3, 9, 10, 11). At the Delta Center Soil Lab, low yielding rice grown in 2012 with center pivot was Si deficient (Fig. 1). In 2009, rice under the pivot in the same field exceeded 200 bu/acre following 2 tons of lime (12). We do not know if the difference was caused by weather or Si availability.

![Figure 1. Colorimetric test for silicon content in straw tissue from aerobic rice grown with center pivot irrigation, dryland wheat, and anaerobic rice from flood irrigation. Dark color indicates high Si content.](image)
University of Florida silicon methods for testing soil and rice straw were used (13). The lab procedures were developed for the Everglades area where Si deficiency is common in rice fields. In 2012, Missouri rice straw from center pivot rice averaged 2.7% Si as compared to 4.8% Si from high yielding flood irrigated fields (14). Based on rice straw, 960 lb Si/acre is recommended by UFL for fields testing less than 3.4% Si. Missouri soil samples from graded rice fields with deep cuts averaged 22 lb Si/acre. Fields with sandy areas tested 3.4 lb Si/acre. Based on soil, UFL recommends 1250 lb Si/acre for fields testing less than 48 lb Si/acre.

This project will leverage grant money provided by the U.S. Rice Foundation to study rice varieties and water management in seven states. Silicon and lime treatments were not included in the multi-state study. Testing for types of arsenic in grain is expensive ($220 per sample). In the Rice Foundation grant, 86% of funds will be used in testing the rice grain for species of arsenic. The remaining 14% is budgeted for soil redox potential equipment. No money was budgeted for labor, field supplies, or travel.

**Plan of Work.**

Six rice varieties and hybrids will be grown in four irrigation management schemes.

1. Continuous flooding in the drill-seeded, delayed-flood cultural system
2. Aerobic rice grown with furrow and sprinkler irrigation†. Irrigate based on daily evapotranspiration from weather station. Redox sensors to assure aerobic conditions.
3. Intermittent flood irrigation (continuous flood for 2-3 weeks), then allow the flood to subside until mud is exposed, followed by pumping the field back to the 2-4 inch depth
4. Arkansas straighthead reduction program – Flood 10 days to 2 weeks followed by draining until soil cracks (aerobic) following by re-flooding until draining for harvest.

† The Delta Center is the only location among the seven states in core study with a center pivot available for rice.

The core study fund by U.S. Rice Foundation will be expanded by adding silicon and lime treatments within irrigation management schemes # 1 and 2. In our test, aerobic rice will be evaluated in furrow row and center pivot irrigated main plots. Initial soil samples will be collected and tested for pH, P, and K, Si, Ca, Mg, S, organic matter and CEC. Three rates of each fertilizer and lime treatment will be tested with four replications. Silicon fertilizer will be applied as calcium sulfate from steel mill slag and liquid potassium silicate. Lime will also be applied (calcite and dolomite) in treatments. Liquid potassium silicate will be applied by fertigation through the center pivot system.

Fertilizer and lime treatments will be applied on three rice varieties. In the core study, six entries will be selected based on information gathered from the 19 cultivars that were included in the 2012 quality study conducted in Texas, Louisiana, Mississippi, Arkansas, and Missouri. Grain from each of the six entries will milled at one location (LSU) and analyzed for inorganic As by a lab approved by FDA. Though LSU will mill samples, each university will be billed for their respective samples. In addition, soil and water from each location will be analyzed. Finally, soil redox potential will be measured in each irrigation treatment area.
Budget - three year total $26,491

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References