ANNUAL REPORT COMPREHENSIVE
RESEARCH ON RICE
March 1, 2017 – December 31, 2017

PROJECT TITLE: Determination of Arsenic Speciation in Rice and Environmental Samples

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LEVEL OF 2017 FUNDING: $30,693

OBJECTIVES AND EXPERIMENTS CONDUCTED:

<u>California Rice Research Station, Biggs, CA</u>

The objectives of this continuing project include: 1) to evaluate the impact of straw management on arsenic (As) uptake into rice grains; 2) compare arsenic (As) levels in rice fields under alternate wetting and drying (AWD) which have received either one or two dry-down events during the growing season; 3) to use soil chemical analysis, including soil redox status as related to arsenic (As) and iron (Fe) in the root zone, to fundamentally understand the mechanisms for arsenic availability to rice; and 4) use collected data to optimize the timing and frequency for AWD management for minimum As accumulation in rice grains.

To accomplish the first objective, arsenic levels were analyzed in 25 samples collected at harvest in 2016, following various different winter straw treatments (2015-2016), which included: burned, bailed, fallow, incorporated, and bailed/burned.

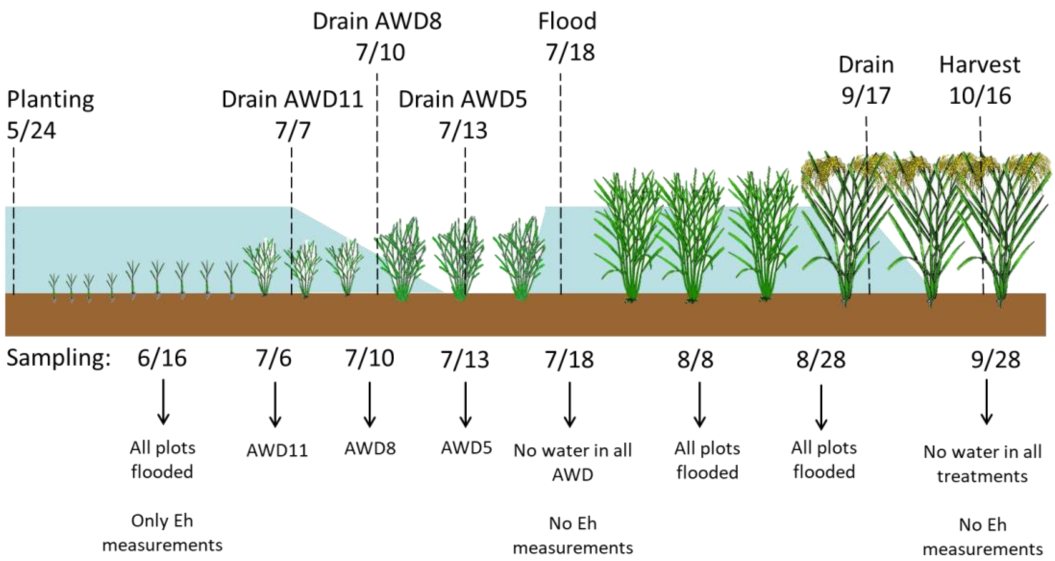

Figure 1. Timeline of AWD practices and sampling dates for 2017.

For the second and third objectives, four irrigation treatments, including one continuous flooding (CF) and three alternate wetting and drying (AWD), were conducted over a growing season at the California Rice Research Station (955 Butte Highway, Biggs, CA 95917). The three AWD treatments received only one dry down event of 5, 8 and 11 days. The 2017 growing season timeline with the AWD treatments and sampling times is shown in Figure 1. Samples taken include soil and plant tissues, and measurements of soil redox potential. Analysis of As (total and speciation) of plant tissues was performed in Parikh's and Green's labs at UC Davis.

SUMMARY OF 2017 RESEARCH (major accomplishments)

Objective 1: We analyzed arsenic levels (total and speciation) in 25 rice grain samples. Results were compared by straw management treatment and by grower. The data did not show a singnifcant difference for As levels in rice grains based on one year of straw management. An important finding to note, is that many the grain samples measured had inorganic As levels above the FDA proposed action level (100 μg/L) for infant rice cereal.

Objectives 2 and 3: We sampled and analyzed plants and soil subjected to AWD treatments under one dry down. There is ongoing analysis of arsenic levels in rice plant samples and soil. Soil redox potential was monitored during the growth season with an Eh meter. The data show that soil redox levels diminish with prolonged flooding and increase following a dry down period. Importantly, the longer the dry down period the longer the soils remain oxic following flooding. This is expected to have important ramifications for As accumulation in the rice grains. Analysis of plant tissue and grain samples is ongoing.

Results from 2016 harvest: We analyzed total and speciation of As in shoots, roots and grains, as well as total Cd contents in different rice tissues. The results confirm results from prior years, showing decreased As uptake with 25 and 35 MCV AWD Treatments. Importantly, the Safe AWD did not show to be effective at reducing As accumulation in grains. Cd contents were shown to increase with the AWD treatments, but levels remained low and are not of concern.

PUBLICATIONS OR REPORTS:

No publications within this reporting period. Two oral reports were given: 1) Georgia State University, Department of Geoscience on March 23, 2017 and 2) California Rice Research Board on December 5, 2017 at UC Davis.

CONCISE GENERAL SUMMARY OF CURRENT YEAR'S RESULTS:

For the 2016 samples, the results are consistent with what has been found in 2015. Total As concentrations in roots and shoots (Figure 2) showed similar trends over the course of the growth season with a decrease during the vegetative growth stages (early tillering to full tillering), because of the biomass dilution effect, followed by an elevation again during reproductive growth (around the time of panicle initiation). Total As contents in ultimate grains (Figure 3), under different treatments, were well paired with the corresponding As uptake in roots and translocation in shoots at maturity. Consistent with 2015, effectiveness of AWD25 and AWD35 was still revealed in 2016 on total As reduction in rice grains, compared with CF, while insignificant difference was observed between AWDS and CF in 2016.

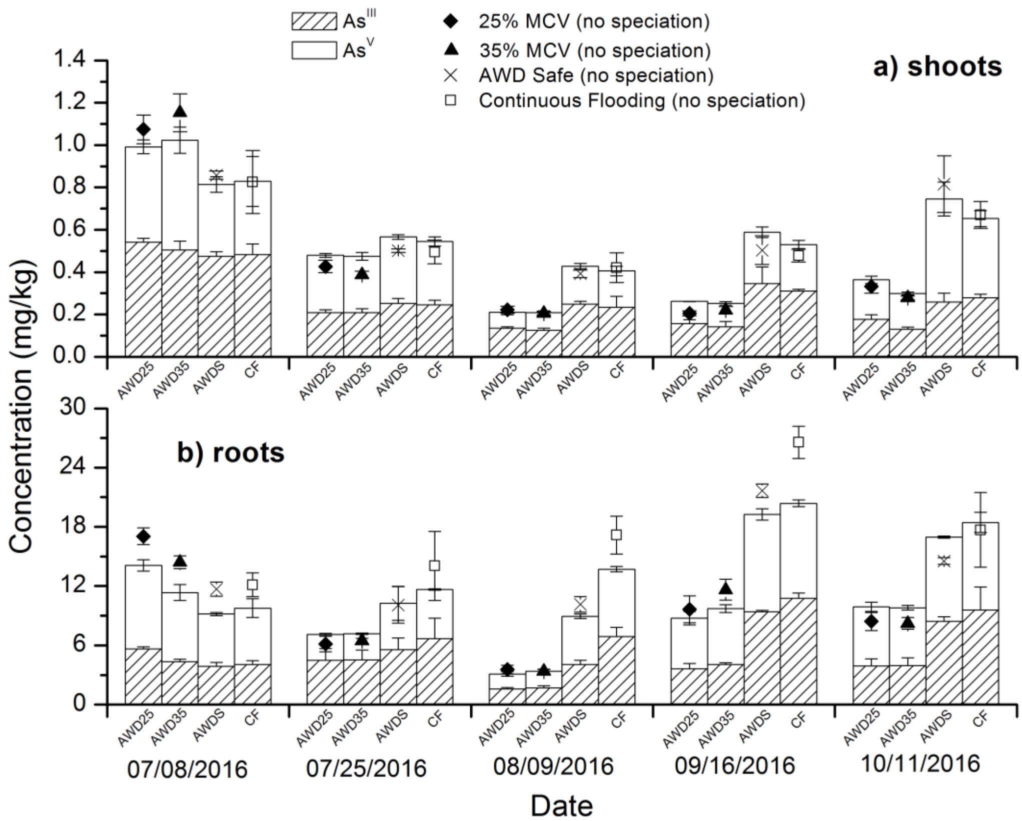

Figure 2. As concentrations (total and speciation) in rice shoots (a) and roots (b) throughout the growing season in 2016.

Irrespective of irrigation practices, the distribution of As in different components of mature rice plants followed the following order: root >> shoot > husk > bran > endosperm. Roots contained markedly higher As than other parts of the rice because the iron (Fe) plaque formed on the surface of the rice roots sequestered a considerable amount of As (88-95%). Total As level of roots without Fe-plaque was on the same order of magnitude as that in corresponding shoots (Table 1) although the former was still 1.9-3.6 folds higher. It is also observed that flooded conditions favor Fe-plaque formation compared to aerated conditions (Table 2) and there was a positive correlation between the Fe content and the As concentration on the root surface. Therefore, it is necessary to investigate whether the Fe-plaque formation is the source or sink of the As entering the rice tissues in the future.

Table 1. Concentration of arsenic in root, root without plaque and shoot (samples from 2016).

	Total As (mg/kg)		
Treatment	Root	Root without plaque	Shoot
AWD25	8.4 ± 0.9	0.62 ± 0.10	0.33 ± 0.03
AWD35	8.2 ± 0.6	0.70 ± 0.06	0.28 ± 0.01
AWDS	14.5 ± 0.3	1.69 ± 0.19	0.82 ± 0.13
CF	17.7 ± 3.8	2.41 ± 0.28	0.67 ± 0.06

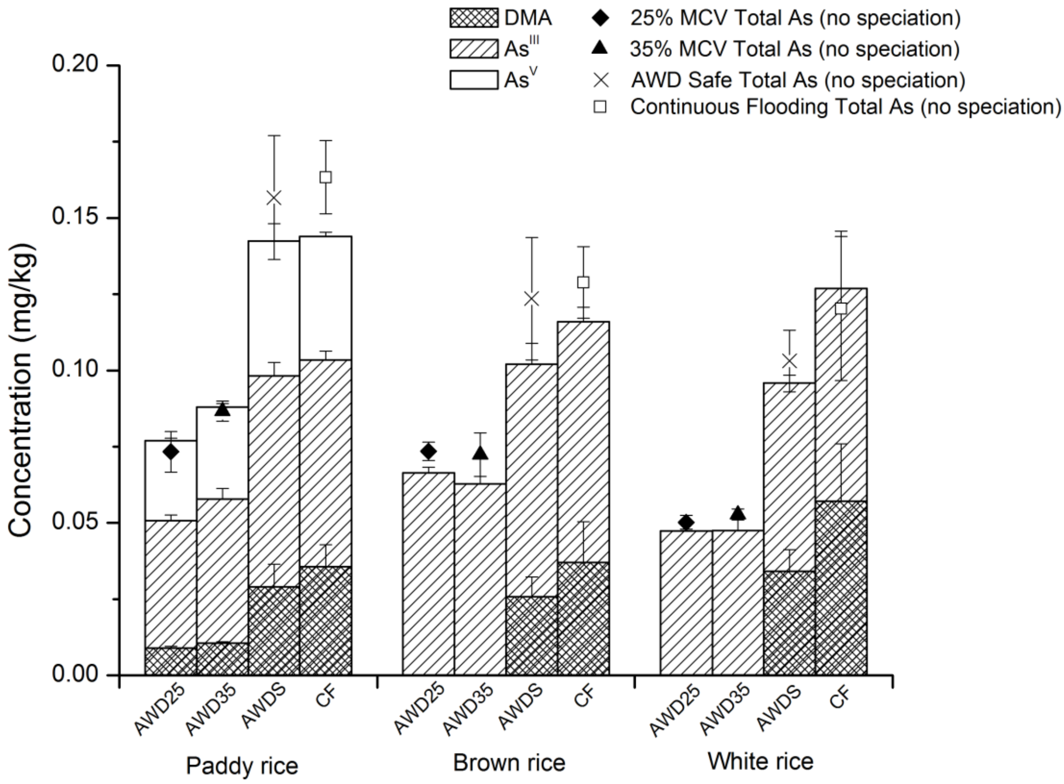

Figure 3. Concentrations of different arsenic species and total arsenic in rice grains harvested in 2016.

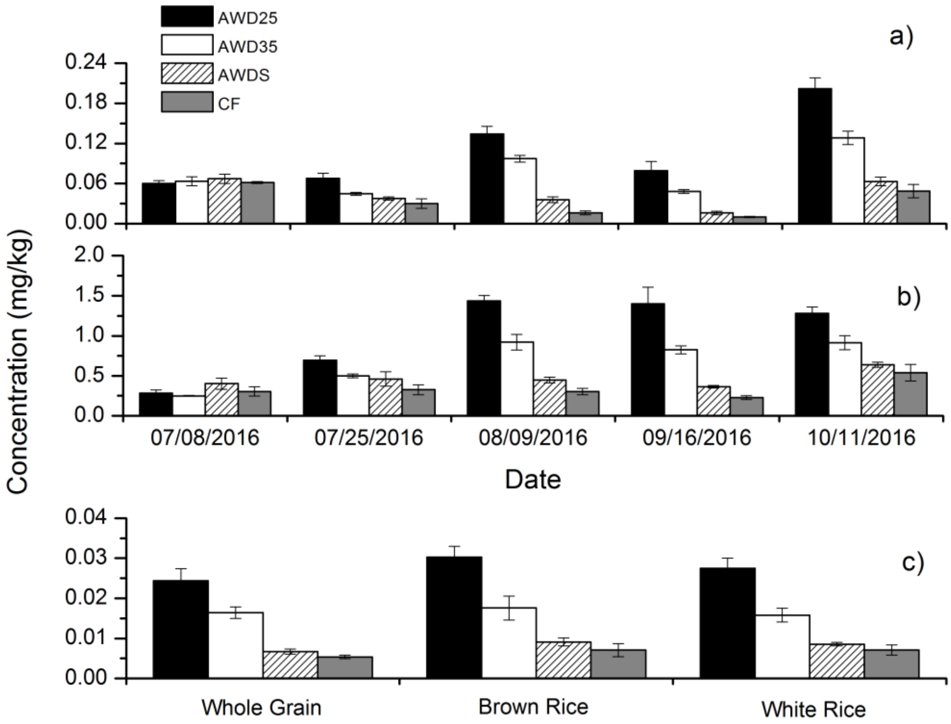

Figure 4. Concentrations of total cadmium in: a) shoots; b) roots; c) grains from year 2016.

The concentrations of Cd in various plant tissues all showed opposite trends towards those of As (Figure 4). Specifically, at maturity, CF and AWDS accumulated the least Cd in roots, shoots or grains, and the Cd level in the white rice under the AWD25 practice was about five-fold higher than CF. However, AWD35 reduced about 40% Cd content in brown and white rice compared to AWD25. In this sense, AWD35 may represent an ideal management strategy for minimizing Cd and As uptake simultaneously.

Table 2. Elemental analysis of the plaque on the root surface.

Treatment	Fe (% weight in plaque)	As (mg/kg iron plaque)
AWD25	23.4 ± 7.4	45.5 ± 7.9
AWD35	21.5 ± 2.6	57.8 ± 5.3
AWDS	41.0 ± 0.5	102 ± 1.2
CF	48.3 ± 2.4	110 ± 6.0

The potential of straw management to minimize As uptake in rice was also evaluated (Figure 5). The winter straw treatments (2015-2016) included: burn, incorporated, fallow, bailed and bailed/burned. No MMA was observed in any of the samples. The treatment with the highest concentration of As is bailed/burned, but the error bars are large and the analysis will be repeated for these samples. No general trend is observed by straw management treatment.

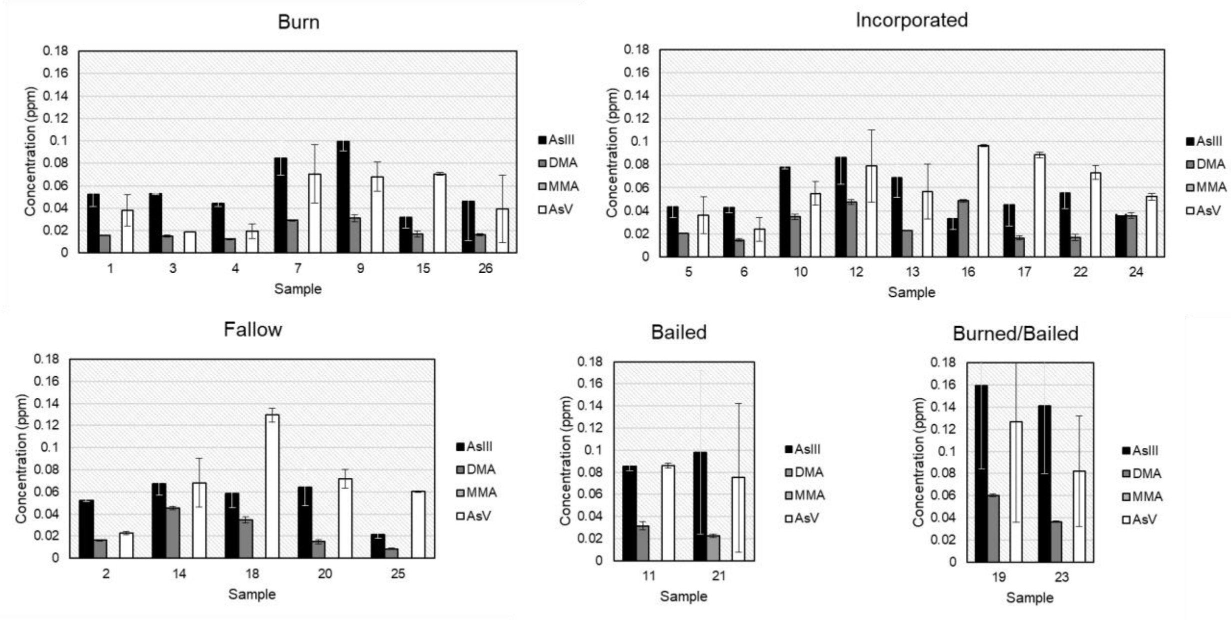

Figure 5. As concentrations (speciation) in brown rice for different straw management treatments

For the 2017 growth season, the redox potential was monitored (Figure 6). Figure 1 indicates that the AWD fields were reflooded after the single dry down period on 7/18. Following this dry down an increase of soil redox potential is observed. The increased Eh remains longer for treatments with longer dry down periods. This indicates oxidizing conditions in soil, which may be related to the immobilization and accumulation of As in soil. The grain and plant tissue analysis from 2017 samples is ongoing.

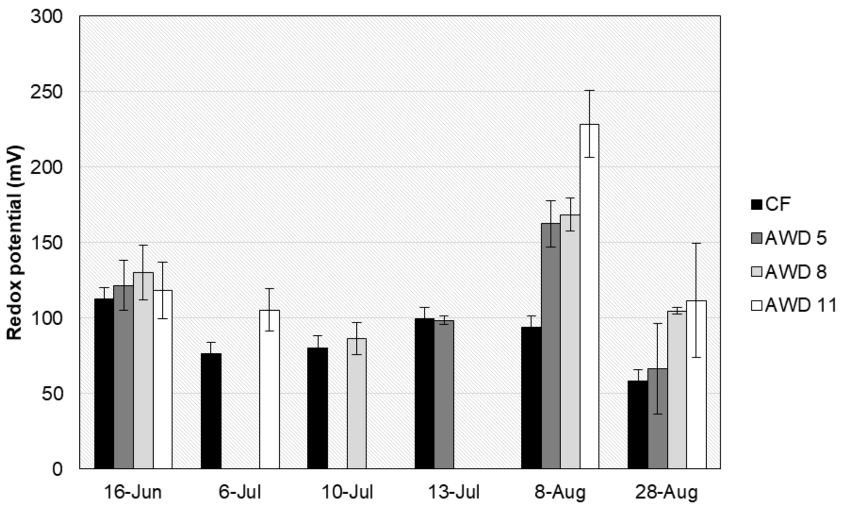

Figure 6. Soil redox potential levels for 2017 growth season