ANNUAL REPORT COMPREHENSIVE
RESEARCH ON RICE
March 1, 2018 – December 31, 2018

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

PROJECT LEADER: Sanjai J. Parikh, Department of Land, Air and Water Resources, University of California, One Shields Avenue, Davis, CA 95618

PRINCIPAL UC INVESTIGATORS: Sanjai J. Parikh, Department of Land, Air & Water Resources; Peter G. Green, Department of Civil & Environmental Engineering; Bruce Linquist, Department of Plant Sciences

LEVEL OF 2018 FUNDING: $19,325

OBJECTIVES AND EXPERIMENTS CONDUCTED:

California Rice Research Station, Biggs, CA

The objectives of this continuing project include: 1) To continue investigating how iron speciation and redox conditions impact arsenic levels in rice under alternate wetting and drying (AWD) treatments; 2) to evaluate the impact of AWD in plant nutrition and grain quality by analyzing phosphorus, nitrogen, iron and zinc in rice grain; and 3) to utilize data collected in objectives 1 and 2 to better elucidate the role of AWD in the uptake of nutrients and contaminants by rice plants.

To accomplish the first objective, 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, two had an early season dry down for 5 and 11 days (E5, E11), and one received a late dry down for 11 days (L11).

The 2018 growing season timeline with the AWD treatments and sampling times is shown in Figure 1. Samples taken include soil and plants, and measurements of soil redox potential (Eh) and pH. Analyses of As in grain and plant tissues were performed in Parikh’s and Green’s labs at UC Davis.

For the second objective, grain samples from years 2015, 2016, 2017 and 2018 were analyzed for nutrient content among the different AWD treatments applied every year. We quantified the concentrations of phosphorus, iron, zinc and potassium in white and brown grain.

Finally, we evaluated the results collected for the first and second objectives to understand changes in concentrations of contaminants and nutrients in grain and plants due to different AWD treatments. For this objective, statistical analyses of these data are still ongoing.

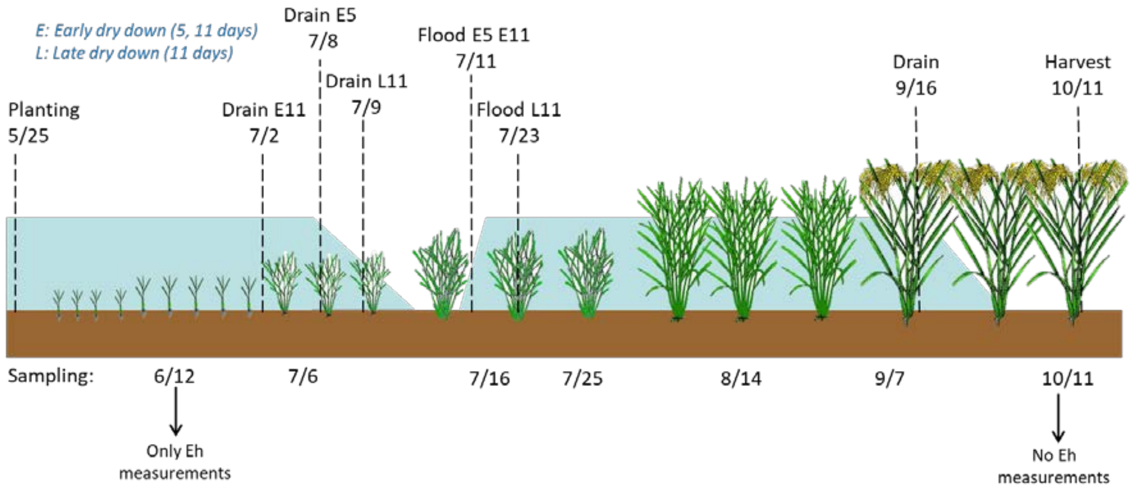

Figure 1. Timeline of AWD practices and sampling dates for 2018.

SUMMARY OF 2018 RESEARCH (major accomplishments)

<u>Objective 1:</u> We sampled and analyzed plants and soil subjected to AWD treatments under one dry down. There is ongoing analysis of arsenic levels in shoots and roots. Soil redox potential was monitored during the growth season with an Eh meter, as well as soil pH. 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 impact As accumulation in the rice grains. Concentrations of As in both white and brown grain decreased with the longer AWD treatments. Cadmium concentrations in grain were inverse from As, increasing with AWD treatments, though levels remain low enough here to not be of concern. Analysis of plant tissue is ongoing.

<u>Objective 2:</u> We analyzed phosphorus, iron, zinc and potassium concentrations in white and brown grain samples from 2015, 2016, 2017 and 2018, to determine the impact of different AWD treatments in grain quality. AWD does not negatively impact the concentrations of these nutrients in rice.

<u>Results from 2017 harvest</u>: We analyzed total and speciation of As in shoots and grains, as well as total Cd concentration in grain. The results confirm trends from prior years, the more sustained AWD treatments decrease concentrations of As consistently along the growing season. Cadmium levels increased with AWD treatments, but remained below levels of concern.

PUBLICATIONS OR REPORTS:
For the current one year reporting period, three papers were published/accepted associated with this project: 1) Li, C. D.R. Carrijo, Y. Nakayama, B.A. Linquist, P.G. Green, and S.J. Parikh. 2019. Impact of Alternate Wetting and Drying Irrigation on Arsenic Uptake and Speciation in Flooded Rice Systems. Agric. Ecosyt. Environ. *Accepted; 2)* Carrijo, D., C. Li.

S.J. Parikh. and B. Linquist. 2019. Irrigation management for arsenic mitigation in rice grain: timing and severity of a single soil drying. Sci. Total Environ. 649:300-307; 3) Carrijo, D. N. Akbar, A. Reis, S.J. Parikh, P.G. Green, A. Gaudin, C. Li, and B. Linquist. 2018. Impacts of variable soil drying in Alternate Wetting and Drying rice systems on yields, grain arsenic concentration and soil moisture dynamics. Field Crops Res. 222:101-110.

Four oral reports were given: 1) Aguilera et al., Agricultural and Environmental Chemistry Graduate Group annual colloquium on March 8, 2018 and 2) Parikh et al., California Rice Research Board on November 28, 2018 at UC Davis; 3) Parikh et al., Evaluation of Alternate Wetting and Drying to Reduce Arsenic Uptake in Rice. 2018 ZJU-UCD Joint International Symposium on Soil-Plant-Microbe Interactions. May 21-22, 2018. Zhejiang University, Hangzhou, China; 4) Li et al., Paddy water management to minimize arsenic and cadmium uptake in Rice. 2018 Sino-US Soil Remediation High Level Symposium. Weifang Sino-US Food and Agricultural Innovation Center. May 25-26, 2018. Weifang, China.

Additionally, one poster presentation at Rice Field Day on August 29, 2018 at Rice Experiment Station; and a future poster presentation at the SSSA meeting on January 8, 2019.

CONCISE GENERAL SUMMARY OF CURRENT YEAR'S RESULTS:

For the 2018 rice grain samples, the results were consistent with previous years. As observed in Figure 2, arsenic concentrations were reduced by AWD treatments. Lower concentrations were achieved for the longer dry downs and for the later drain, compared to early. These results are lower than the FDA's proposed action level for infant rice cereal of 0.1 mg/kg, even for brown rice, which are higher than white rice. Even though the AWD treatments were effective in reducing As uptake into rice grains, the cadmium concentrations follow an inverse trend, where the higher severity of the dry downs increased Cd content in grain (Figure 3).

Soil redox potential was monitored during the growing season. As shown in Figure 1, dry down periods for all treatments occurred from 7/2 to 7/23. We can observe in figure 4 that the redox potential increases after reflooding the soils, for the early treatments on 7/16, and for the late treatment on 7/25. Soil redox potential lower than 100 mV indicates reducing conditions, which means arsenic is very mobile in soil and is likely to be taken up by the rice roots and translocated into the grain. After the soils have been reflooded, the redox potential increases significantly, and is higher for the L11 treatment. This trend is consistent with the As concentrations in grain, L11 had the highest increase of redox potential and the lowest concentration of As.

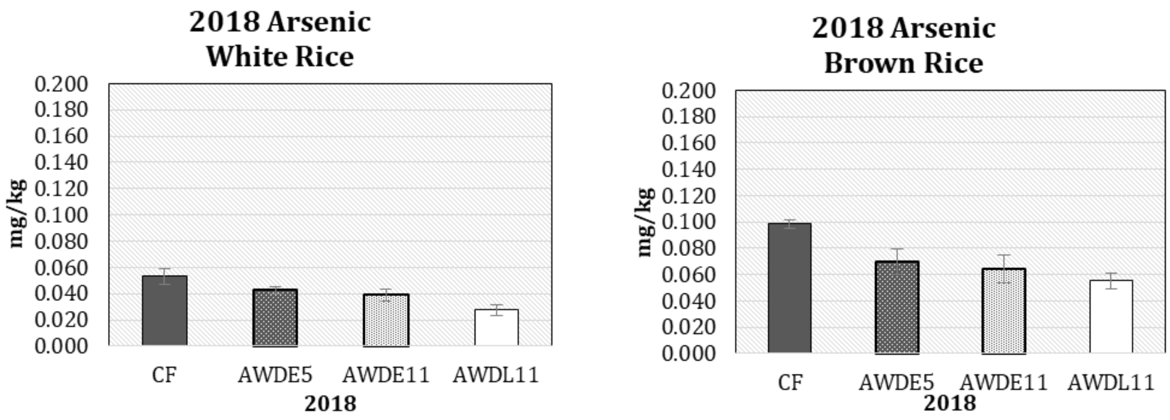

Figure 2. Concentration of total As in white and brown grain.

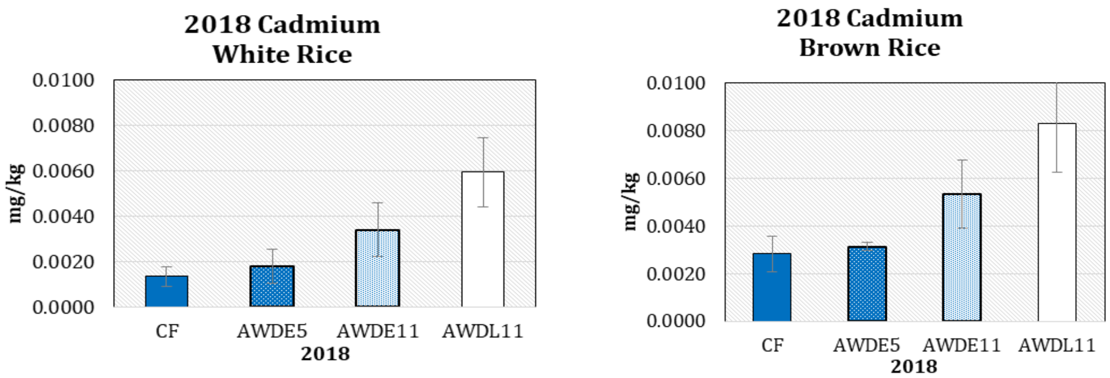

Figure 3. Cadmium concentrations in white and brown grain.

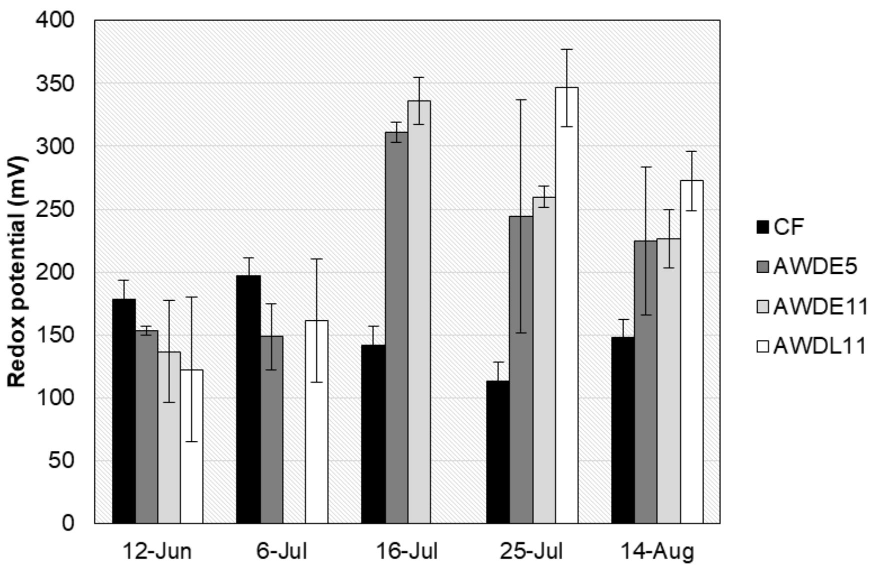

Figure 4. Soil redox potential levels for 2018 growth season.

Soil pH levels (figure 5) were in a range between 5.12 and 7.96. Overall, they increased along the season for all treatments, though this increase was less significant with AWD treatments of the longest dry down period.

We analyzed nutrient concentrations in white and brown grain for years 2015, 2016, 2017 and 2018. We have studied the effect of AWD in the accumulation of contaminants in rice, though we aimed to identify the impact of AWD treatments in nutrient levels of grain. Figure 6 shows the phosphorus concentrations of white and brown grain for each year. We can observe a slight increase of the concentration of total phosphorus with AWD treatments (about 20% for the treatments with longest dry down periods). Phosphorus levels are higher for brown rice than for white, and the concentrations vary from year to year, which is expected from higher concentration of nutrients in bran.

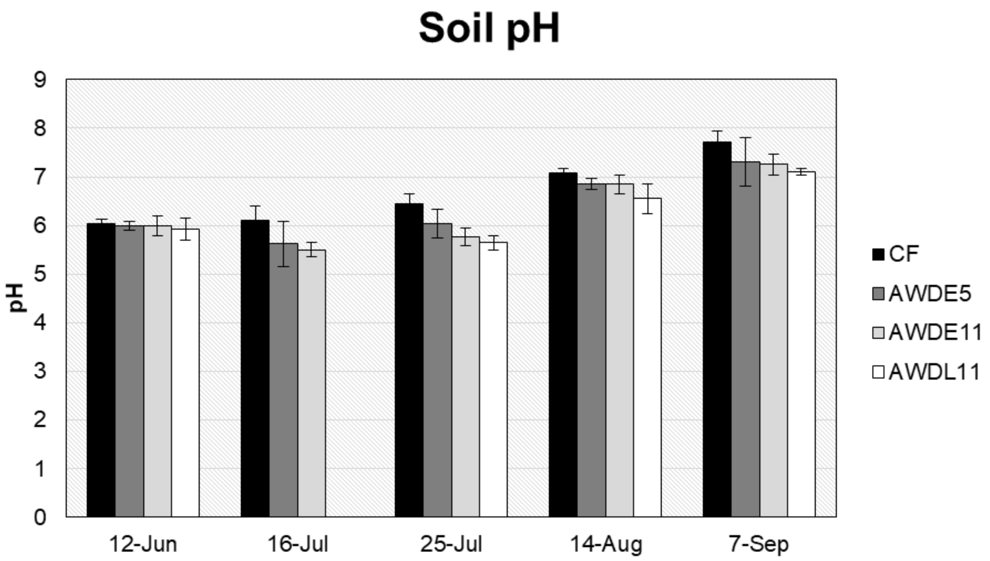

Figure 5. Soil pH levels for 2018 growth season.

We observed the same trends for iron, zinc and potassium concentrations in grain, though iron levels varied more within each year.

The analysis of nutrients in plants can be related to not only grain quality but also uptake of contaminants. For example, under certain conditions, the oxidized species of inorganic arsenic can behave as a phosphorus analogue, which competes for the transporter sites and is taken up by rice plants. It is important then to analyze the results collectively. These results indicate that there is not an evident competition between P and As related to the translocation of these elements to grain.

The potential of AWD treatments to minimize As uptake in rice is evident for our 2018 results and previous years. We had not previously studied other properties of rice that AWD could impact. The analysis of nutrient concentrations in grain was an important step in assessing possible effects of AWD treatments in grain quality. We can conclude from our results that AWD has no significant impact in concentrations of P, Fe, Zn and K in grain, which is a positive finding for recommending AWD treatments to growers.

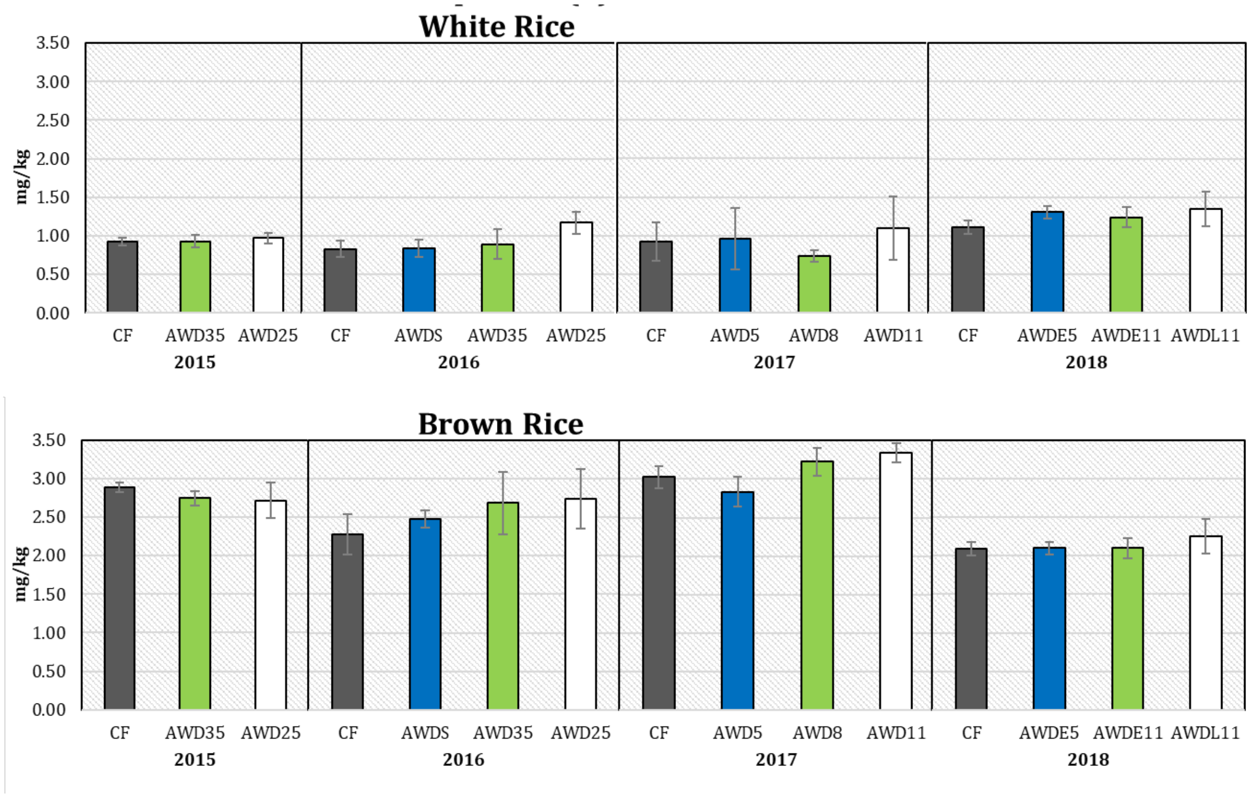

Figure 6. Phosphorus concentrations in white and brown grain for all years.