ANNUAL REPORT COMPREHENSIVE RESEARCH ON RICE
January 1, 2017 - December 31, 2017

PROJECT TITLE:
Improving fertilizer guidelines for California's changing rice climate.

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OBJECTIVES AND EXPERIMENTS CONDUCTED, BY LOCATION, TO ACCOMPLISH OBJECTIVES:

The overall objective of this project is to develop fertilizer guidelines for California rice growers which are economic viable and environmentally sound. Toward this objective, in 2016 the following specific objectives were addressed.

1) Determine the potassium status of rice soils.
2) Develop management practices for growing rice under conditions of alternate flooded/dry soil conditions.
3) Understand and quantify rice yield variability in the Sacramento Valley
4) Improving fertilizer N use efficiency
   a) Mid-season N status and accessing the need to topdress.
   b) Completing the N budget of California rice systems

SUMMARY OF 2017 RESEARCH (major accomplishments), BY OBJECTIVE:

1. Determine the potassium status of rice soils.

NOTE: the section below is largely unchanged from last year. Our main objective was to complete this study by determining the mineralogy of the soil and how that relates to the potassium fixation we are seeing (particularly in the SE portion of the valley). The X-ray diffraction machine was very problematic and only recently have we been able to get any data-which remains unanalyzed, as we have not had time to complete.

In 2012 and 2013, 55 rice fields were identified. From each field, soils samples (from the top, middle and bottom checks), water samples (twice each season from inlet) and flag leaf samples at heading were all analyzed for K. In addition, each grower was asked about historical (past 5 years) yields from fields, straw management and winter flooding practices.

Soil K values ranged from 35 to 350 ppm (critical level-60 ppm). There was no relationship between soil K values and the amount of K that had been added and removed (based on recent history data). The primary pattern we saw was that soil K values were lowest in the south-east, followed by north-east and north-west. Highest values were in south-west. All fields below 60 ppm (critical value) were on the east side of the valley.

The critical flag-leaf K value is considered to be 1.2%. When soil K values were below the critical value of 60 ppm then 50% of the flag leaves sampled had K values below the critical range and when soil K ranged from 60 to 120 ppm, 8 flag leaf samples (24%) had K levels below the critical range (Fig. 1-1). Based on this data, we suggest when soil K levels are below 120 ppm, that K fertilizer should be considered.

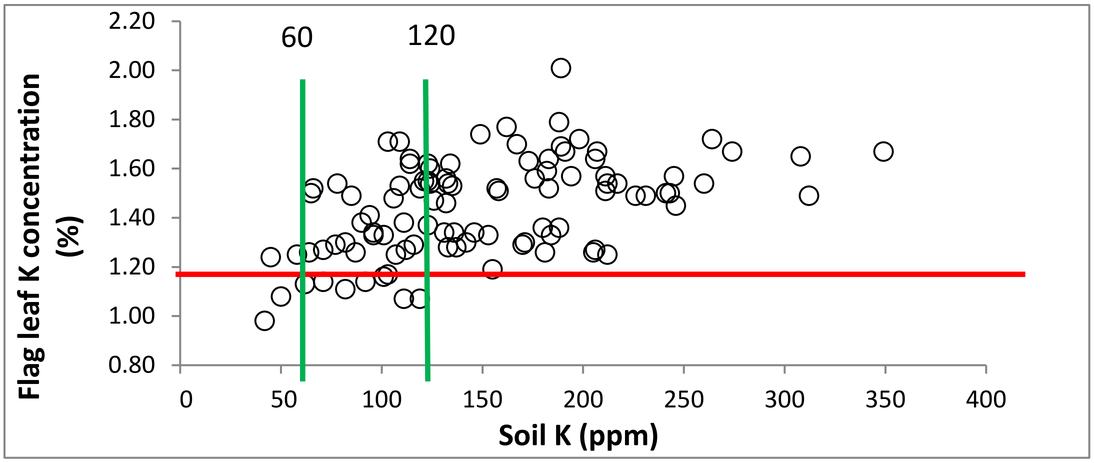

Figure 1-1. The relationship between soil K and flag leaf K values in 2012 and 2013 fields where K fertilizer was not applied.

There was a significant difference in the concentration of K in irrigation waters. Of the two primary rivers, the Sacramento River had the highest K values (1.18 ppm) while the Feather River averaged 0.79 ppm. Well water had the highest overall K concentration (2.3 ppm) but it was also highly variable. Recycled irrigation water averaged 1.4 ppm and was also variable.

K fixation can significantly impact soil K. When K is fixed, it is trapped within soil particles, making it unavailable to plants and absent in soil K tests. K fixation is suspected to be why no relationship was found between the amount of K added or removed from a field and soil K. In 2016, to understand how much K these rice soils can fix, the K fixation potential (Kfix) was measured. Kfix is a metric of the soil's potential to fix or release K. Kfix values ranged from 242 ppm K (fixing 242 ppm) to -554 ppm K (releasing 554 ppm). Of the 160 total soil samples (from 55 fields), 25 samples fixed K and 135 samples released K. There is a clear relationship in which soils that fix K are likely to have lower soil K (Figure 1-2). Also, all soils that fix K have a soil K concentration under 200ppm, indicating that soils with lower K levels are possibly fixing K.

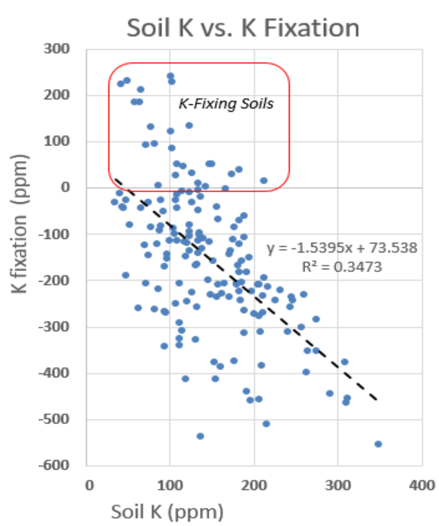

Figure 1-2. The relationship between K Fixation and Soil K. The soils circled in red are those that fix K.

K fixing soils were primarily found in the eastern Sacramento Valley (Figure 1-3a). Of the 25 soil samples that fixed K, 22 (88%) were east of the Sacramento River. As mentioned, soil K follows a similar distribution in which soils in the eastern Sacramento Valley had lower soil K values (Figure 1-3b). Of the 59 soil samples deficient in K, 51 (86%) were also east of the Sacramento River. As some soil types fix K while others do not, Web Soil Survey information was used to identify which soil types (using SSURGO map units) are capable of fixing K (Figure 1-4). Map units 824, 825 and 886 were soils that fixed K, while all other map units studied did not fix K. Growers can use the interactive Web Soil Survey to understand if their fields contain these K fixing soils and potentially adjust their management practices. In 2017, we plan to determine the mineralogy of these soils which will make it easier to identify K fixing soils and thus for growers to make fertility adjustments.

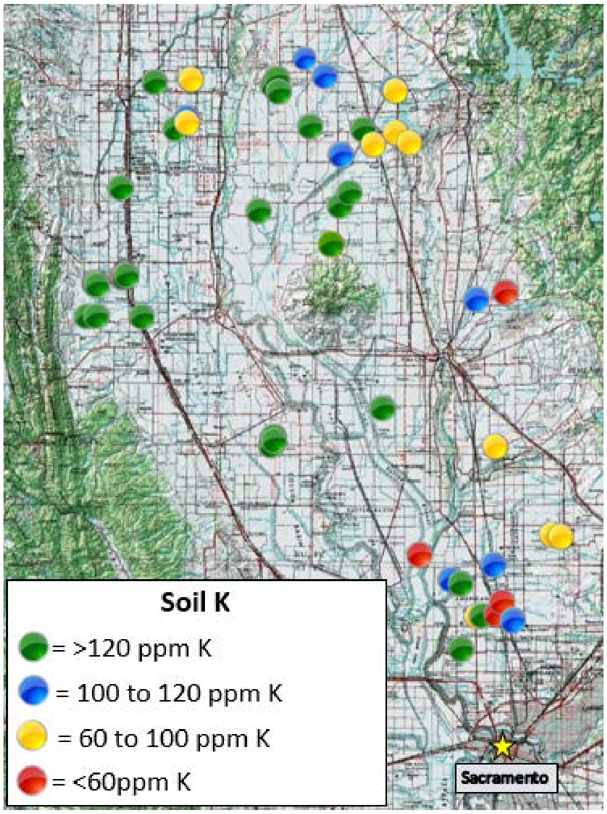

Figure 1-3a. This map shows the distribution of soil K levels. The soils with K levels below the critical value of 120 ppm are mostly located to the east of the Sacramento River.

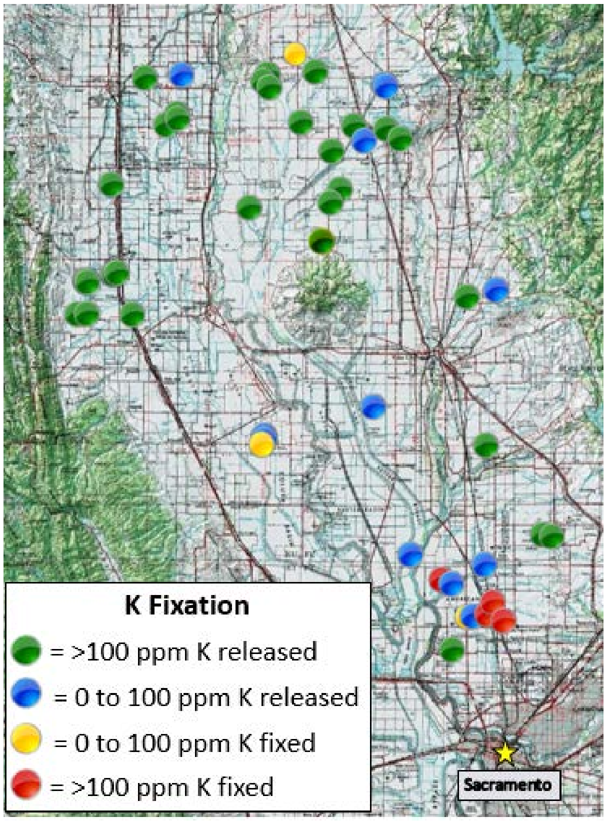

Figure 1-3b. This map shows the distribution of the K fixation. Fields marked with red and yellow circles fix K, while those marked with blue and green circles release K. Soils that fix K are also mostly located to the east of the Sacramento River.

To improve our understanding of K fixation in Sacramento Valley rice fields, we are in the process of analyzing soil mineralogy. Our analyses have revealed which soils fix K, but understanding exactly where K is fixed will help guide K management. Currently, underway is an X-ray diffraction analysis of soil mineralogy to identify if it is vermiculite, smectite, or other minerals that are trapping the K that growers are applying. We have had problems with the X-ray diffraction machine and this has delayed results. Once the mineralogy of these soils are known, our improved understanding of K fixation will help develop improved K management guidelines to help growers overcome plant K deficiencies.

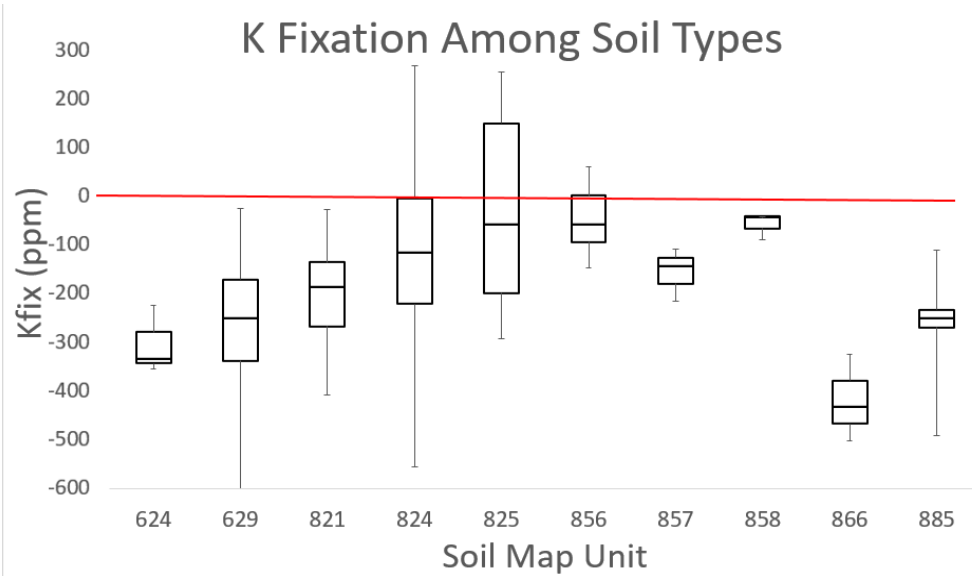

Figure 1-4. A "box-and-whisker" plot of the K fixation potential of the different soil types analyzed (based on SSURGO data). Soils that reach above the red line fixed K.

2. Develop management practices for growing rice under conditions of alternate flooded/dry soil conditions.

Background

While the conventional system of growing rice under continuously flooded conditions produces good grain yields and maintains high nitrogen use efficiency, California rice growers should be prepared for situations where they might face conditions (limited water availability) or legislative pressure to implement alternative water management strategies. For example, concerns have been raised about the high greenhouse gas emissions associated with continuously flooded rice fields, as well as arsenic uptake by rice plants and methyl-mercury formation in flooded soils. The alternation of wet (flooded) and dry (drained) conditions, known as AWD, has the potential to mitigate some of the aforementioned problems. While these problems don't currently necessitate an alternative water management strategy, it is important to evaluate the agronomic viability of AWD as a potential option.

Recent research (2012 to 2016) that has evaluated growing rice in CA under conditions where the soil alternates between wetting and drying (we will refer to this as alternate wet and dry –AWD) has shown that rice yields can be maintained provided the soil does not dry out too much during the drainage events. It is important to understand at what times during crop growth the crop is most susceptible to unsaturated soils and how dry the soil can be before yields are reduced. Our broad objectives for this research are to (1) further develop AWD management practices that are viable for California and compare them to conventionally flooded rice and (2) identify sensitive periods in crop growth where unsaturated soil conditions can lead to yield reductions, and (3) determine the critical level the soil can dry to before negatively impacting yield. This research will demonstrate whether or not AWD is viable and if not, will provide the data for an economic analysis of what are the additional costs of using AWD production systems to mitigate environmental concerns.

Progress to date

Research on AWD from 2012 to 2016 where we had two dry down periods of varying intensity (2 to 12 days) between 45 DAS and heading indicate:

- Regardless of dry-down severity (up to 10-12 days drying) we have seen no evidence of yield reductions relative to the continuous flood control. This is likely due to roots that go down to over a foot deep into soil layers that are not as dry.
- Nitrogen and weed management are the same for AWD as for the control. All dry downs are done after fertilizer N is taken up and canopy cover is achieved.
- Methane emissions are reduced by 40 to 90%. Nitrous oxide emissions are negligible because dry downs occur when there is low soil mineral N.
- Arsenic and methyl-mercury concentrations in the grain are reduced by over 50%. However, in Safe-AWD where dry downs were only 2-3 days As concentrations were not reduced.

When evaluating the timing (PI, booting, heading) of a single dry down and its affect on As grain concentrations, research from 2015 and 2016 in ring studies show that:

- Results indicated no yield reduction relative to a continuously flooded treatment.
- In both years grain As concentrations were lower when the dry down was imposed at PI or booting rather than at heading;
- however, the impact of timing on decreasing grain As concentration was less important than the impact of soil drying. The drier the soil during the dry down the greater the reduction in grain As.

2017 Field Research

All field studies to date have examined the effects of two drains. In 2017, we focused on a single drain. This drain occurred between 36 and 46 days after planting (roughly at PI). The reason for this, is that due to cool temperatures during booting, we do not want to recommend a drain at this time (growers are encouraged to raise flood water heights to protect emerging panicle). Second, this is the time that appears to have the greatest effect on grain As concentrations.

In addition to conducting research at the RES, in 2017 we investigated AWD practices on-farm at three locations.

Rice Experiment Station

In 2017, we had the following treatments replicated 3 times at the RES:

1. CF (continuously flooded - conventional)
2. AWD 5 (soil is allowed to dry for 5 days, starting at 41 days after sowing)
3. AWD 8 (soil is allowed to dry for 8 days, starting at 38 days after sowing)
4. AWD 11 (soil is allowed to dry for 11 days, starting at 36 days after sowing)

The rational for these treatments is that AWD 8 and AWD 11 correspond to the previously tested AWD35 and AWD25, respectively, and AWD 5 represents a slightly drier treatment than Safe AWD, which did not have a sufficient dry period to decrease grain As concentrations (see previous reports). Soil moisture was monitored to quantify dry down events, GHG emissions were quantified, and all samples analyzed for grain As.

The dry downs in AWD 5, AWD 8 and AWD 11 started at 36, 38 and 41 days after planting, respectively, and were all refolded at 46 days after planting. One plot from the AWD 11 treatment was infested with weeds due to a faulty herbicide application and had to be excluded from the yield dataset. Yields and some yield components are presented in Table 2-1. Data on GHG emissions and grain arsenic concentrations will be forth coming.

Table 2-1. Yields and some of the yield components for AWD treatments and CF control in RES. Number are averages of three plots (except for AWD 11 with two plots), followed by the standard error in parenthesis.

	CF	AWD 5	AWD 8	AWD 11
Yield (lbs/ac)	9,776 (396)	9,116 (159)	9,184 (351)	8,382 (264)
Harvest Index (%)	50 (0.5)	50 (0.5)	49 (1.3)	46 (2.9)
Tillers per m^2	144 (5)	133 (5)	156 (7)	161 (10)
Panicles per m^2	135 (9)	131 (7)	146 (9)	134 (7)

Yields were significantly lower in the AWD-11 than in the continuous flooded treatment. AWD 5 and 8 were also lower but not significantly so. This is the first year we have seen such a reduction in yields. It is not clear if the yield reduction was due to the abnormally warm year or the fact that we imposed the drain earlier in the season (this year drains were about 1 week before previous years). What is evident is that the AWD 8 and 11 resulted in the production of more tillers which were unproductive. Thus, energy was used for tiller production at the expense of grain.

Grower field study

Since 2012 we have conducted these experiments on-station and have never seen a yield reduction. Given 5 years of such results, we tested AWD in three commercial grower's fields. The fields were in different parts of the valley (Arbuckle, Sacramento and Glenn) so we had different soils, climate and management practices represented. In each field, we assigned one check for the CF conventional and another check for

AWD 5 (i.e. same as treatment 2 conducted at RES). The AWD check was in the bottom check in the Glenn and Sacramento sites and the top check in the Arbuckle site. We measured yields, GHG emissions, soil moisture, and grain As.

The dry downs of the AWD checks in Glenn, Sacramento and Arbuckle started at 37, 38 and 47 days after planting, respectively. The AWD checks in Glenn and Sacramento experienced a 6-day drying period, which was close to what we aimed for (AWD 5). However, in Arbuckle the AWD experienced only a 2-day drying period; this check took a long time to drain off the floodwater (likely because the field had little slope). Reflooding of the AWD checks took less than a day in all sites.

Yields and some yield components are presented in Table 2-2. In general, yields were similar between the AWD and CF checks. Lower yields in the Arbuckle AWD check is most likely due to this check being a cold-water check. As seen at RES, the dry-down resulted in increased tiller number but in these cases these were productive tillers. One issue in doing this on-farm was coordinating the dry-down with the various herbicide applications.

Table 2-2. Yields and some of the yield components for AWD and CF in the three commercial sites. Number are averages of four measurements taken per check, followed by the range in parenthesis.

	Sacramento		**Glenn**		**Arbuckle**	
	AWD	**CF**	**AWD**	**CF**	**AWD**	**CF**
Yield (lbs/ac)	11,188 (11,058-11,354)	10,887 (10,192 - 11,336)	10,325 (9,886 - 10,872)	10,911 (10,595 - 11,473)	11,978 (11,173 - 13,065)	12,671 (11,790 - 13,596)
Harvest Index (%)	54 (51 – 56)	56 (53 – 57)	55 (54 – 56)	56 (54 –58)	49 (48 – 51)	52 (51 – 53)
Tillers per m^2	191 (180 – 206)	175 (160 - 190)	162 (146 - 173)	138 (132 - 143)	164 (144 - 185)	162 (156 - 172)
Panicles per m^2	191 (180 – 206)	173 (160 - 190)	161 (143 - 173)	135 (129 - 140)	163 (185 - 144)	162 (156 - 172)

3. Understand and quantify rice yield variability in the Sacramento Valley

California rice yields are amongst the highest in the world; however, over the past 15 to 20 years' yields have stagnated. Our objective is to identify ways to further increase yields through improved management that optimizes the yield potential of the varieties being developed.

Broadly, the objectives of this research were as follows:

- Create a database of Statewide Variety Trials, state and county yield data, grower yields, and other yield data that is accessible to multiple research groups for analysis.
- Analyze yield trends across time, estimating the impact of soils, management, and climate variability.
- Conduct a Yield Gap Analysis

- Highlight areas of improvement or future research in support of increased yield and yield stability in CA rice production.

This work was largely completed in 2016 (see report). In 2017, time was devoted to wrapping up the analysis and publishing the results (see reports at the end). A summary of our results is as follows:

1. ORYZA was able to model yield potential in the Southern US (CXL745) after only basic calibration compared to CA (M-206). ORYZA was less able to simulate yield potential in CA (M-206) rice production systems in the Delta region due to cold induced sterility. This work was published in Field Crops Research, Volume 193 (May), 2016 titled "Estimating yield potential in temperate high-yielding, direct-seeded US rice production systems."
2. The current attainable yield potential in California rice systems with modern medium grain varieties was between 11,200 to 12,500 lbs/acre, while the Southern US had generally lower yield potential between 10,500 to 11,200 lbs/acre. Of this, 85% is typically assumed to be attainable by farmers.
3. The actual statewide yields in CA averaged between 7,700 to 8,600 lbs/acre.
4. The yield gap (the room for potential improvement) is therefore smaller in CA (between 1,000 to 1,500 lb/acre) and larger for Southern US systems (between 1,500 lbs/acre to 2,600 lbs/acre).
5. California rice production systems generally had higher yield potential compared to production systems in the Southern US. However, production systems in CA also showed lower annual yield improvements compared to the Southern US, suggesting that CA rice systems might be closer to a yield ceiling.
6. Using the probability based model, the impact of cool stress during booting had the largest impact on grain yield (up to 2,500 lbs/acre yield loss). Cooling or heat stress during flowering were found to have the next largest impact on grain yield behind cooling stress during booting. Warmer seasonal T_{min} and T_{max} were found to have much smaller impact on yield (less than 400 lbs/acre yield loss; approximately 1-2% per ℃). This estimate of yield losses due to increased seasonal T_{min} is much smaller than previous estimates (10% loss per ℃; Peng et al., 2004).
    a. From a management standpoint, this finding emphasizes the importance of raising water between PI and heading to protect the emerging panicle from cold.
7. Sensitivity to cooling and heating stress during booting varied by grain type, with medium and short grain types estimated to be more resistant to cooling stress and long grains estimated to be more sensitive. Sensitivities to cool stress during flowering were similar between grain types. Long grains were found to be the least sensitive to heat stress during flowering compared to short and medium grains.
    a. From a breeding standpoint, this finding emphasizes the need for continued development of cold tolerant varieties.

4. Improving fertilizer N use efficiency.

a. Mid-season N status and accessing the need to topdress

Overview

This study was initiated in 2015 to evaluate the potential of sensor based technologies to access N status in rice and determine the need for top-dress applications. N response trials were established in two locations with 5 preplant N rates ranging from 0-200 lbs. N/ac (applied as urea). We found that GreenSeeker NDVI measurements taken at PI accurately determined total N uptake in rice, but not biomass and N concentration. In 2016, the experiment was repeated to confirm this result, as well as determine which NDVI value (and amount of N in plant at PI) would indicate the need for a top-dress application. N response trials were established in three locations with 5 preplant N rates ranging from 0-200 lbs. N/ac. Additionally, at PI each plot was split into three subplots receiving 0, 23, and 45 lbs. N/ac top-dress. The strong correlation between NDVI measurements and total N uptake observed in 2015 was confirmed in 2016. Additionally, from the yield results it was estimated approximately 120 lbs. N/ac are required to be taken up by the crop at PI to achieve maximum yields, which corresponds to a NDVI value of approximately 0.75. Furthermore, yield results indicated that PI N Uptake was a strong predictor of crop response to adding top-dress, as applications beyond the 120 lbs. N/ac threshold led to high yield penalties. By contrast, NDVI and Response Index (max observed NDVI/treatment NDVI) did not correlate strongly with crop response. Lastly, as we expected based on our previous research, splitting N applications between preplant and top-dress did not result in a significant yield increase.

Research from 2017

<u>Methods</u>

Based on our encouraging results from 2015 and 2016, we replicated the 2016 experiments in order to improve the accuracy of our estimates as well as incorporate the use of a drone in our work for wider application. N response trials were established in three locations with seven N rates ranging from 0-250 lbs N/ac each replicated four times. At PI, each plot was further split into three plots receiving top-dress N at rates of 0, 23, and 45 lbs. N/ac. The following specific measurements were taken at each site:

Soil at each location at start of season were analyzed for total N, organic C, pH, and texture

1. At PI
    a. aboveground biomass from each N plot was analyzed for weight, N concentration and total N uptake.
    b. Green Seeker NDVI
    c. Drone flying with an NDVI camera
2. At Harvest
    a. Above ground biomass and yield. Samples were analyzed for weight, N concentration and total N uptake.

<u>Results</u>

Data were compiled from 2015 – 2017 and analyzed together. Key research findings are:

1. NDVI measured with a GreenSeeker can accurately access PI N uptake in rice (Fig 4-1). This correlation is strong and consistent across sites and years. By comparison, the

relationship between NDVI and biomass or N concentration exhibited significant variation across site-years.

2. 94 lbs. N/ac (+/- 6 lbs. N/ac.) are required by the rice plants at PI to achieve maximum yields (Figure 4-1d). Despite three years with highly variable yield potential, the amount of N required to achieve maximum yields remained consistent and constricted to a narrow range.
3. Based on the previous two findings we can determine that a NDVI value of 0.65 or above at PI indicates the crop is N sufficient (Figure 4-1c).
4. PI N Uptake helped provide guidance on potential crop yield response to top-dress, but it is not perfect. Similarly, the use of NDVI or a Response Index (based on NDVI measurements) also provide guidance on the potential usefulness of a top-dress N. <u>Preliminary</u> analysis suggests that a top dress is needed when:
    a. PI N uptake is <110 lb N/ac (Figure 4-2),
    b. An NDVI reading of <0.7 (Figure 4-2),
    c. A Response Index of >1.1 (Figure 4-3).
5. Splitting N applications between preplant and top-dress does not provide a significant yield advantage (Figure 4-4). Analysis of two years of data (5 total sites) does not show a significant advantage to split application across a range of N rates.

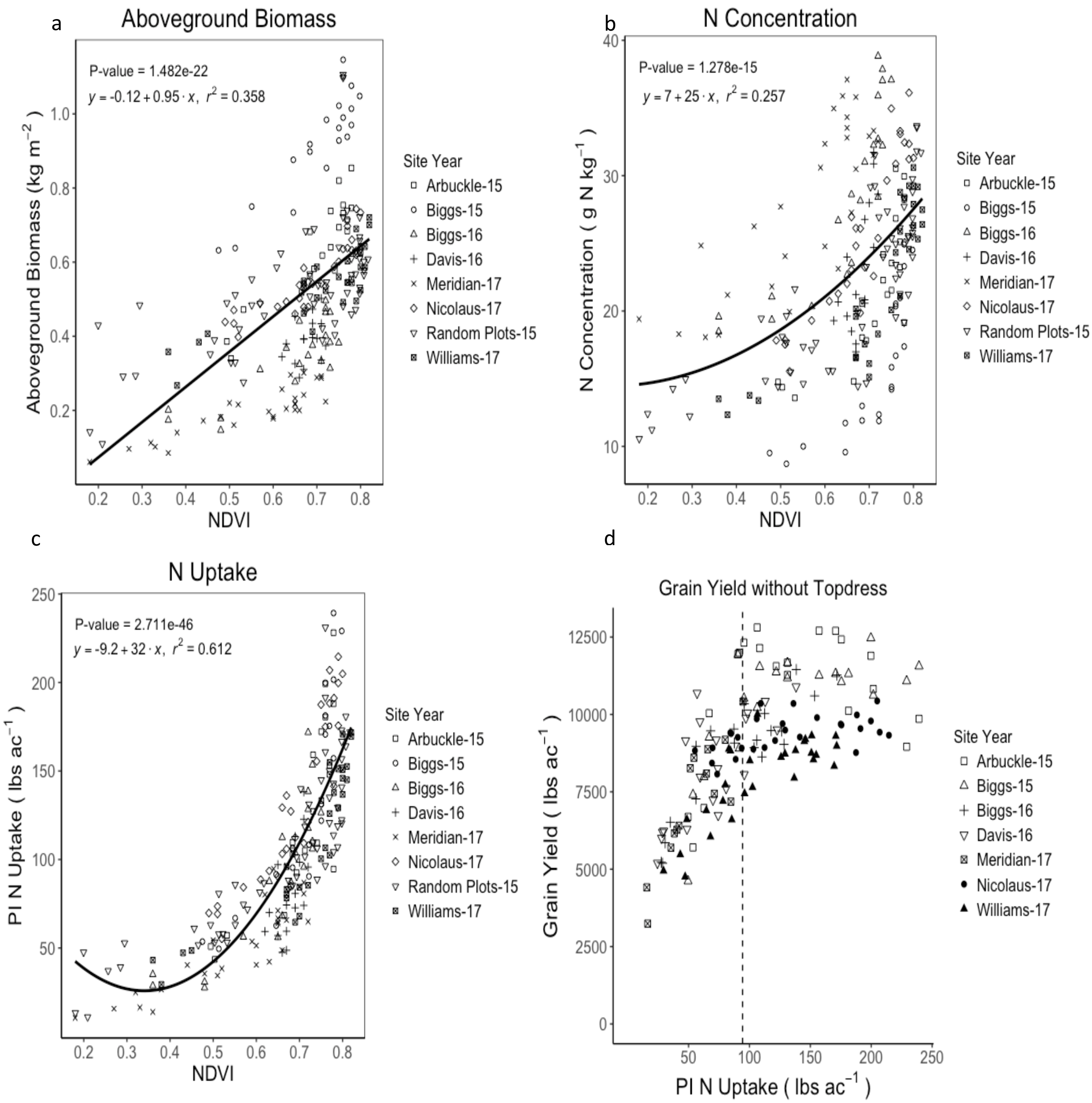

Figure 4-1 (a-c): Relationship between GreenSeeker NDVI and aboveground biomass, N concentration, and PI N Uptake across all site-years (2015-2017).

Figure 4-1 (d): Relationship between PI N Uptake and Final Grain Yield (without adding topdress) across all site-years (2015-2017). Yields plateau at 94 lbs. N/ac.

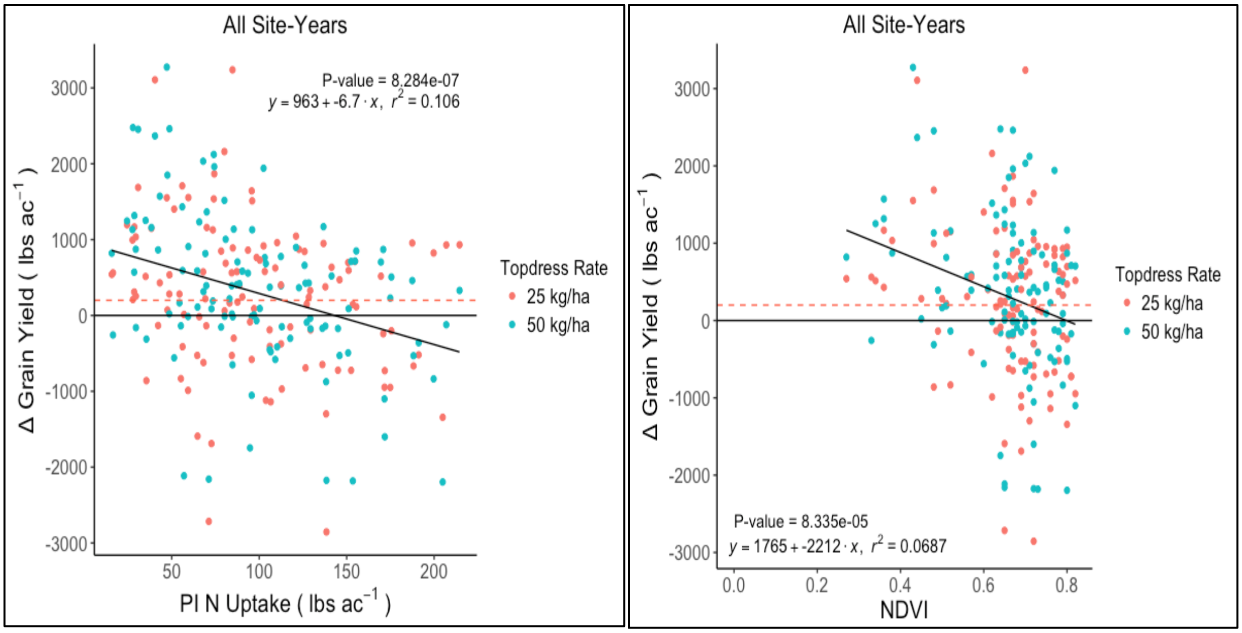

Figure 4-2. The response of rice grain yield to top-dress N application at two rates of topdress. Points above the line indicate a yield increase and points below the line a yield decrease. This yield response is evaluated relative to N uptake at PI or the GreenSeeker NDVI measurement which provides a good estimate of N uptake at PI (Figure 4-1).

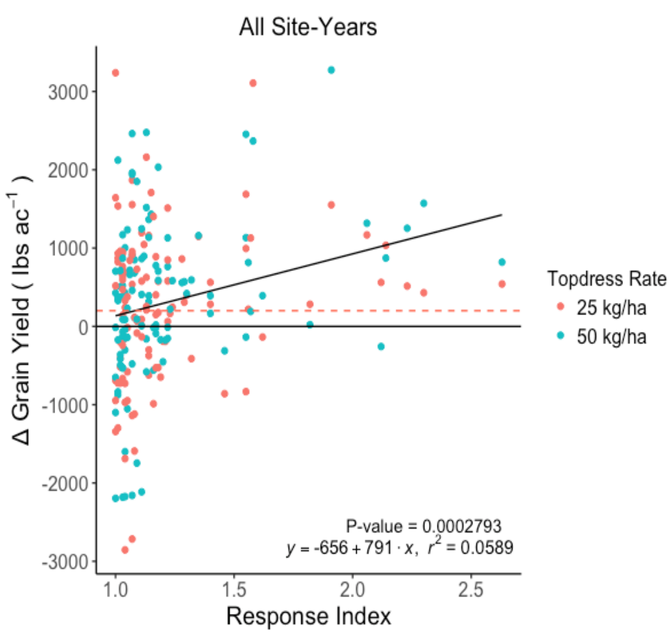

Figure 4-3. The response of rice grain yield to top-dress N application at two rates of topdress. Points above the line indicate a yield increase and points below the line a yield decrease. This yield response is evaluated relative to the Response Index.

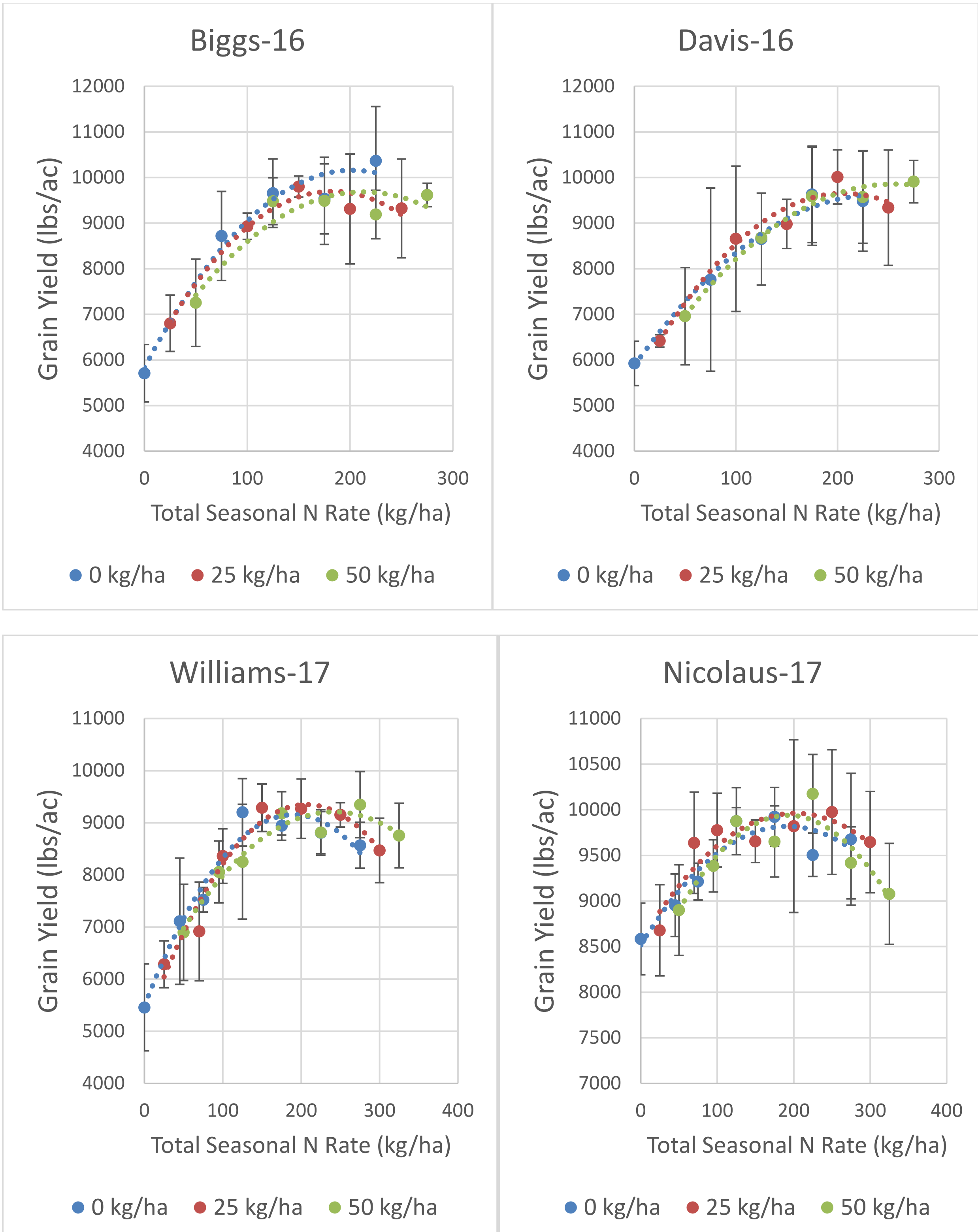

Figure 4-4. Relationship between total applied N and grain yield. Graphs show effects of applying all of the N as preplant (0 kg N/ha as topdress) vs spitting the N rate with either 25 or 50 kg N/ha (23 or 45 lb N//ac) applied at PI as a top-dress N application.

b. Completing the N budget of California rice systems

When attempting to improve nitrogen use efficiency (NUE), it is important to understand where rice systems are losing N. Understanding where N is lost is also important in California's increasing regulatory environment. For example, in previous research we were able to show that nitrate-leaching losses were low in rice systems. These findings resulted in the ILRP requiring fewer monitoring wells in the rice region. Through research supported by the RRB (particularly RM-4), much of these loss pathways have been determined. These are:

1. N lost in harvested grain (a desirable loss)
2. N losses through surface tailwater runoff
3. N losses through leaching
4. Losses to nitrous oxide (N_2O – a greenhouse gas)

Loss in the grain is where we would like all of the N to end up; while losses due to run-off, leaching and N_2O are not desirable. Our research show that these "undesirable" N losses in California rice systems are very low, and preliminary analysis suggest they make up roughly only 6% of all the fertilizer N applied. This is good compared to other rice systems globally, as well as compared to other cropping systems. One source of N loss that has not been accounted for is ammonia (NH_3) volatilization. NH_3 is an air quality concern that the California Air Resources Board (CARB) is looking closely at. We have reason to believe NH_3 losses in rice systems are low due to most of the fertilizer being injected below the soil surface, soils that are generally lower than a pH of 7, and cool water temperatures. However, these losses have not been quantified. In 2017 it was our objective to develop a methodology to test NH_3 volatilization and do this on several fields.

2017 Methodology

Ammonia volatilization losses were quantified in 2 commercial grower fields. The methodology used will be that developed by Beyrouty et al. (1988) and successfully used to quantify NH_3 losses in rice systems in the southern US (Griggs et al., 2007). This methodology entails the use of semi-static chambers (tubes) driven into the soil (Figure 4-5). Within each tube is a polyurethane foam absorber to absorb NH_3. These foam absorbers are removed at different time intervals and the NH_3 extracted and quantified. These tubes will be placed within three N treatments in each commercial field.

Three treatments were evaluated and set up with four replications in a randomized complete block design. The treatments were:

1. No fertilizer N
2. Only aqua at the grower rate
3. Urea only at the grower rate

Figure 4-5. Picurtes of the cambers used to measure NH_3 volitlaization in the field. The foam contains phosphoric acid which captures the NH_3.

The tubes were set into the soils (at least 4 inches into the ground). In the aqua treatment they werer put in place immediately after the aqua had been injected. The other tubes were set into soil that had not received any aqua fertilizer. In the urea treatment tube, an amount of urea granules equivalent to the aqua rate were placed in each tube. The 0N tubes received no fertilizer. The sponges were changed at 4 intervals:

1. From time of fertilizer placement to just before flood water reached plots
2. From time flood water reached plots until 1 day after
3. One week after flooding
4. Two weeks after flooding.

After removal of sponges from the tubes they were rinsed in 2M KCL to remove entrapped N. The KCL was then analyzed for NH_4 and NO_3. The amount of N captured was then converted to an area basis.

At both sites NH_3 volatilization in the plots receiving no fertilizer was very low (Figure 4-6). Cumulative NH_3 volatilization from the 0N plots was less than 0.75 lb N/ac (Figure 4-7). Similarly, at both sites, NH_3 volatilization from the aqua treatment was also very low and not significantly different than the 0N treatment. In contrast, NH_3 volatilization in the urea treatment was much higher. NH_3 volatilization was high mostly during the flood up and week after flood up. NH_3 volatilization was much higher at Meridian than Nicholaus being 8 lb N/ac compared to 1.5 lb N/ac. The reasons for this are not clear but one possibility is that at the Merdian site the surface soil was only dry in the top 2 inches and below that it was wet while at the Nicholaus site the seed bed was dry to 6 inches deep. Application of the prilled urea therefore at Nicholaus resulted in a large portion of the urea prills dropping down between the soil clods to deeper depths than at Meidian. We know incorporation of urea helps reduce NH_3 volatilization. In effect, the granules falling down in the cracks were a form of incorporation.

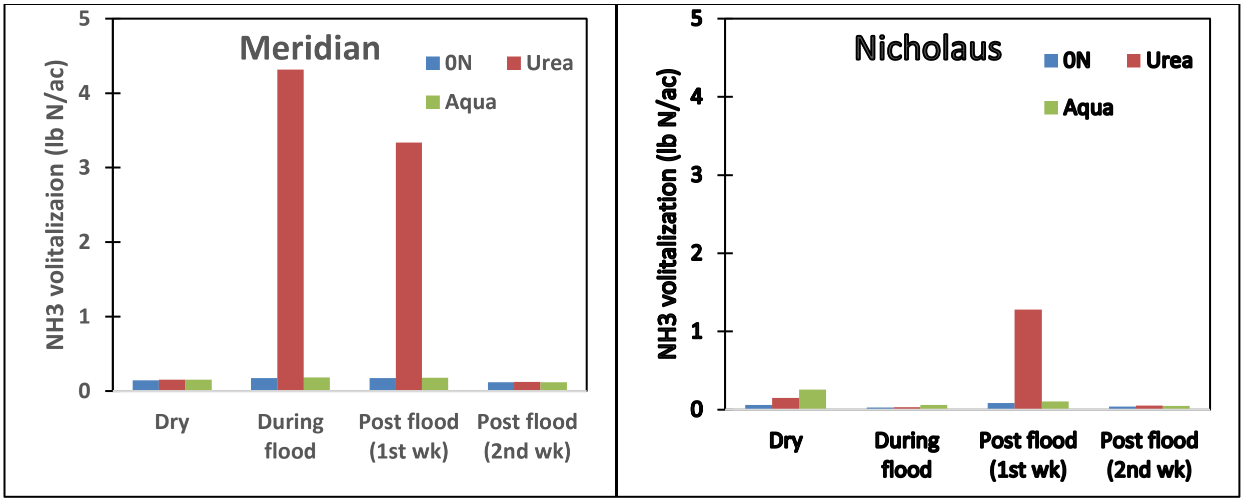

Figure 4-6. NH_3 volatilization at the Merdian and Nicholaus sites

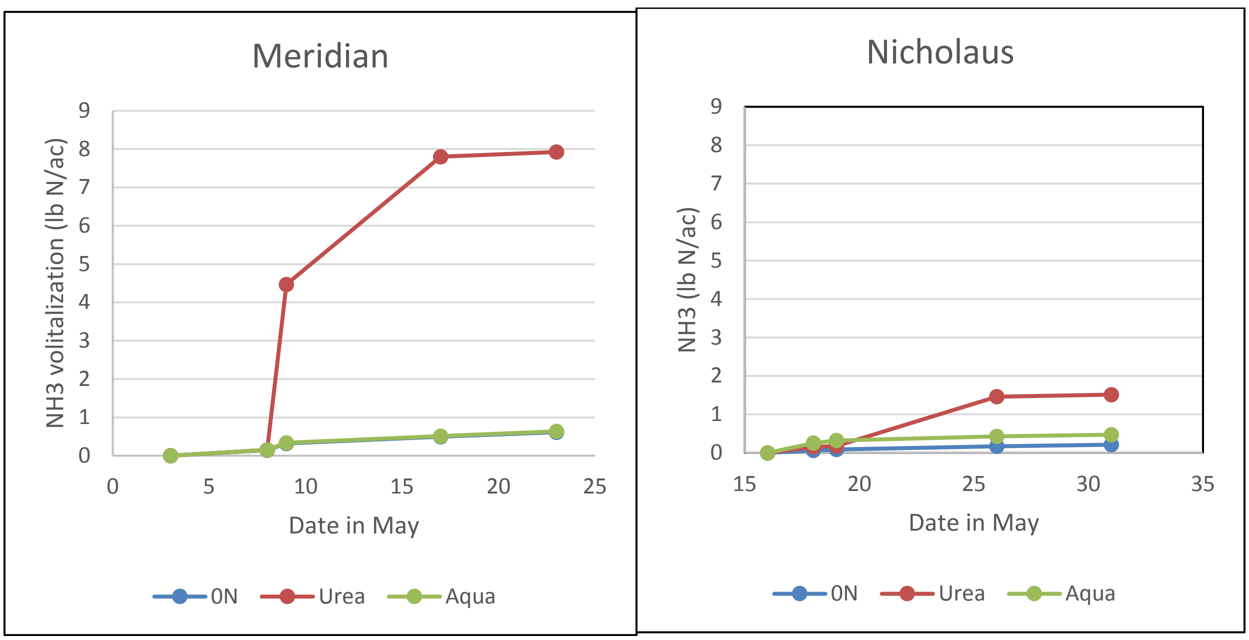

Figure 4-7. Cumulative NH_3 volatilization at Meridian and Nicholaus.

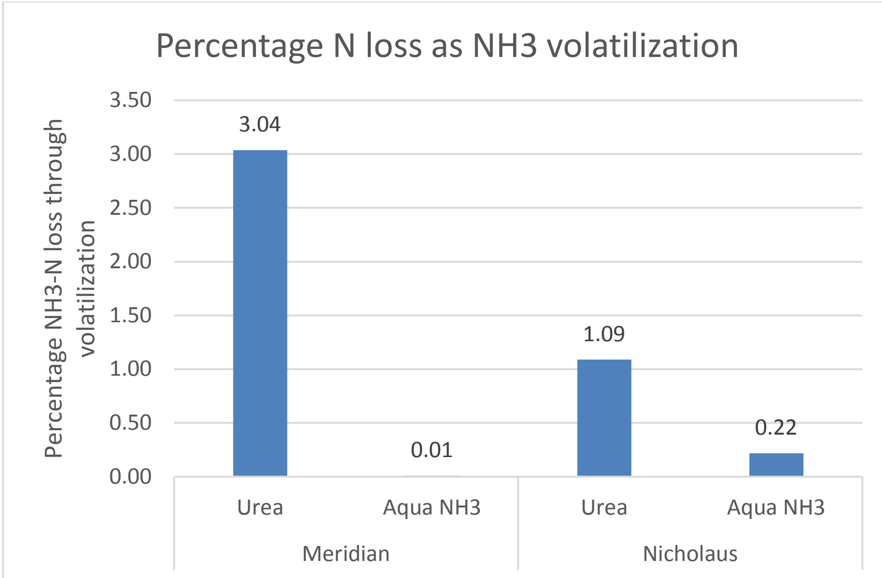

Figure 4-8. The percentage of fertilizer N lost as NH3.

Subtracting the NH_3 volatilization losses from the 0N treatment from the fertilizer treatments indicates that NH_3 volatilization losses from aqua was less than 0.2% (Figure 4-8). In contrast, NH_3 volatilization losses from urea were 3% at Meridian and 1% at Nicholaus.

From this data, it is encouraging to see that NH_3 volatilization losses from the main N source used in California is very low and from an environmental standpoint appears that it should not be a concern. That said, this research was only conducted at two locations in what was an unusual year. We would like to confirm these findings in 2018.

PUBLICATIONS OR REPORTS:

PUBLICATIONS (Rice publications 2015-17):

1. Simmonds, M.B., M. Anders, M.A. Adviento-Borbe, C. van Kessel, A. McClung, and B.A. Linquist. (2015). Seasonal methane and nitrous oxide emissions of several rice cultivars in direct seeded rice systems. Journal of Environmental Quality 44:103-114.
2. Nalley, L. L., B. Linquist, K.F. Kovacs, and M.M. Anders (2015) The economic viability of alternate wetting and drying irrigation in Arkansas rice production. Agronomy Journal 107:579-587.
3. Espe, M.B., E. Kirk, C. van Kessel, W.H. Horwath, and B.A. Linquist. (2015) Indigenous nitrogen supply of rice is predicted by soil organic carbon. Soil Science Society of America Journal. 79:569-576.
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8. Lagomarsino, A., A.E. Agnelli, B. Linquist, M.A.A. Adviento-Borbe, Agnelli, A., Gavina, G., and M. Ravaglia. (2016). Alternate wetting and drying of rice reduced CH_4 but triggered N_2O peaks in a clayey soil of central Italy. Pedosphere 26:533-548.
9. Adviento-Borbe, M.A. and B.A. Linquist. (2016) Assessing fertilizer N placement strategies for lower CH_4 and N_2O emissions in irrigated rice systems. Geoderma 266:40-45.
10. Ye, R., Espe, M., Linquist, B., Parikh, S.J., Doane, T.A., Horwath, W.R. (2016) A soil carbon proxy to predict CH_4 and N_2O emissions from rewetted agricultural peatlands. Agriculture, Ecosystems and Environment 220:64-75.
11. Espe, M. H. Yang, K.G. Cassman, N. Guilpart, H. Sharifi, and B.A. Linquist (2016) Estimating yield potential in temperate high-yielding, direct-seeded rice US rice production systems. Field Crops Research 193:123-132.
12. LaHue, G.T., M.A. Adviento-Borbe, B.A. Linquist, C. van Kessel, and S.J. Fonte. (2016). Residual effects of N fertilization history increase N_2O emissions from zero N controls: Implications for estimating fertilizer-induced emission factors. Journal of Environmental Quality 45:1501-1508.
13. LaHue, G.T., R.L. Chaney, M.A. Adviento-Borbe, and B. A. Linquist. (2016) Alternate wetting and drying in high yielding direct-seeded rice systems accomplishes multiple environmental and agronomic objectives. Agriculture, Ecosystems and Environment 229:30-39.
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22. Geisseler, D., B.A. Linquist and P.A. Lazicki (2017) Effect of fertilization on soil microorganisms in paddy rice systems -a meta-analysis. Soil Biology and Biochemistry 115:452-460.
23. Tanner K., Windham-Myers, L., Marvin-DiPasquale, M., Fleck, J.A. and Linquist, B.A. (In Press). Alternate wetting and drying decreases methylmercury in flooded rice (*Oryza sativa*) systems. Soil Science Society of America Journal.
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PRESENTATIONS (2016, 2017)

Linquist, Bruce. Nutrient management in California rice systems. Rice winter grower meetings. January 26 and 27. Richvale, Willows, Colusa and Yuba City.

Matthew Espe and Bruce Linquist. Temperature impacts on rice yields in California. *ASA, CSSA, SSSA 2017 Annual Meeting; Oct. 22 - 25, Tampa, FL.*

Linquist, Bruce; Espe, Matt. Increasing yields near the yield potential: A case study of rice breeding in California. *ASA, CSSA, SSSA 2017 Annual Meeting; Oct. 22 - 25, Tampa, FL.*

Rehman, Telha; Reis, Andre; Akbar, Nadeem; and Linquist, Bruce. "Improving Nitrogen Use in California Rice", *ASA, CSSA, SSSA 2017 Annual Meeting; Oct. 22 - 25, Tampa, FL.*

Daniela Carrijo, Mark Lundy, Bruce Linquist. 2016. Factors affecting rice yield under alternate wetting and drying irrigation: results of a meta-analysis. Poster at 36th Rice Technical Working Group Meeting - Galveston, TX, USA. March 1-4

Matthew B. Espe, Haishun Yang, Kenneth G. Cassman, Nicolas Guilpart, Hussain Shar-ifi, and Bruce A. Linquist. 2016. Calibration and validation of oryza(v3) for simulation of yield potential in us rice production systems. Poster at 36th Rice Technical Working Group Meeting - Galveston, TX, USA. March 1-4

Daniela Carrijo, Bruce Linquist. 2016. Alternate wetting and drying does not compromise rice yield compared to continuously flooded irrigation. Oral presentation at the CHRIAM INOVAGRI International Meeting 'Leading Technologies for Water Management' - Concepcion, Chile. October 24-26.

Johnny Campbell, Randy Southard, Bruce Linquist. Potassium Availability and Fixation in California Rice Fields. Poster at the Annual Rice Field Day. August 31 2016. Biggs, CA

Telha Rehman, Andre Froes de Borja Reis, Nadeem Akbar, and Bruce Linquist. Remote Sensing to Assess the Midseason Nitrogen Status of Rice. Poster at the Annual Rice Field Day. August 31 2016. Biggs, CA

CONCISE GENERAL SUMMARY OF CURRENT YEAR'S RESULTS:

Objective 1. Determine the potassium status of rice soils.

Plant, soil and water data from the 55 fields sampled in 2012 and 2013 have all been analyzed. In brief, soil K values ranged from 35 to 350 ppm (critical level-60 ppm). There was no relationship between soil K values and the amount of K that had been added and removed (based on recent history data) suggesting that it is not a good management strategy to try to build up soil K but rather apply the amount needed. The primary pattern we saw was that soil K values were lowest in the south-east, followed by north-east and north west. Highest values were in south-west. All fields below 60 ppm (critical value) were on the east side of the valley. The critical flag-leaf K value is considered to be 1.2%. When soil K values were below the critical value of 60 ppm then 50% of the flag leaves sampled had K values below the critical range and when soil K ranged from 60 to 120 ppm, 8 flag leaf samples (24%) had K levels below the critical range (Fig. 1). Based on this data, we suggest when soil K levels are below 120 ppm, that K fertilizer should be considered.

There was a significant difference in the concentration of K in irrigation waters. Of the two primary rivers, the Sacramento River had the highest K values (1.18 ppm) while the Feather River averaged 0.79 ppm. Well water had the highest overall K concentration (2.3 ppm) but it was also highly variable. Recycled irrigation water averaged 1.4 ppm and was also variable.

In 2016 we found that some soils low in available K also were K fixers. That is the soils could bind K in forms that are not available to plants. Such soils require a different K fertility regime. K fixing soils were mostly on the eastern side of the Sacramento River and we were able to identify certain soil types that were prone to K fixation. Differences in K fixation among soils is likely due to differences in soil mineralogy. This will be explored in 2017 and will help refine K fertility recommendations.

Objective 2. Develop management practices for growing rice under conditions of alternate flooded/dry soil conditions.

In 2013, 2014, 2015 and 2016 grain yields in all AWD treatments were the same as the conventional water seeded treatment. Similarly, the optimum N rate required to achieve maximum yields was similar among treatments. Further, we have found that AWD reduces GHG emissions by 57% or more, grain arsenic by 50%, and methyl mercury production. We also tested a Safe AWD system in 2016. In this systems the soils are only allowed to dry for about 2 days before reflooding. Safe AWD reduced methane emissions by 40% (not yet sure of impact on grain As uptake). While such results are encouraging and show the possibility of these systems, it is not clear how easy it would be to implement at the field scale. Research suggests the "window" during which a field can be safely drained is fairly large as fields could dry down to 25% volumetric water content without a yield penalty. This is roughly 12 days, however this may vary depending on location and soil type. We hope to have some field trials in 2017.

Objective 3. Understand and quantify rice yield variability in the Sacramento Valley

In 2016, the focus of our efforts was finalizing the Yield Gap Assessment of US rice systems and determining the primary temperature stresses that impact rice yields in California. Specifically, to date in this project we have:

- ORYZA was able to model yield potential in the Southern US (CXL745) after only basic calibration compared to CA (M-206). ORYZA was less able to simulate yield potential in CA (M-206) rice production systems due to issues with phenology prediction and cold induced sterility.
- The current maximum attainable yield potential in California rice systems with modern medium grain varieties was between 11,200 to 12,500 lbs/acre, while the Southern US had generally lower yield potential between 10,500 to 11,200 lbs/acre. Of this, 85% is typically assumed to be attainable by farmers.
    - The actual statewide yields in CA averaged between 7,700 to 8,600 lbs/acre.
    - The yield gap (the room for potential improvement) is smaller in CA (between 1,000 to 1,500 lb/acre) and larger for Southern US systems (between 1,500 lbs/acre to 2,600 lbs/acre).
- Using the probability based model, the impact of cool stress during booting had the largest impact on grain yield (up to 2,500 lbs/acre yield loss). Cooling or heat stress during flowering were found to have the next largest impact on grain yield behind cooling stress during booting. Warmer seasonal T_{min} and T_{max} were found to have much smaller impact on yield (less than 400 lbs/acre yield loss; approximately 1-2% per ℃; Fig. 3). This estimate of yield losses due to increased seasonal T_{min} is much smaller than previous estimates (10% loss per ℃; Peng et al., 2004).
- Sensitivity to cooling and heating stress during booting varied by grain type, with medium and short grain types being more resistant to cooling stress and long grains more sensitive. Sensitivities to cool stress during flowering were similar between grain types. Long grains were found to be the least sensitive to heat stress during flowering compared to short and medium grains.

Objective 4. Mid-season N status and accessing the need to topdress

After analyzing data from 2 years (2015 and 2016) and multiple sites, we found the Green Seeker NDVI to be a poor indicator of panicle initiation at biomass and of N concentration in the plant; however, it was a good indicator of above ground N content (or total plant N uptake). Given this, it is a potentially useful tool to determine if a top-dress N application is necessary. Our preliminary analysis shows that if N uptake at PI is 120 to 130 lb N/ac, the GreenSeeker NDVI value will be 0.75. An NDVI value lower than this indicates a need for a topdress of N fertilizer. There are more data from this season that we have yet to analyze; however, given these initial promising results, along with the increase availability and use of remotely sensed data, further research in this area is warranted in order to make these tools more promising for growers.