PROJECT NO. RM-4

ANNUAL REPORT
COMPREHENSIVE RESEARCH ON RICE
January 1, 2006 - December 31, 2006

PROJECT TITLE: Improving N use efficiency in rice systems with varying early season water management practices.

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Overarching Project Goal:

The focus of the RM-4 project is to evaluate the impact of grower management practices on nutrient cycling, and to work in association with cooperative extension to develop improved fertility management guidelines for rice growers.

2006 Project Goal:

Develop N fertilizer guidelines for California rice growers practicing alternative early season water management strategies.

To meet this goal, two objectives were addressed:

1. To evaluate and quantify soil and fertilizer N losses as affected by early season water management in rice fields.

2. To improve N fertilizer guidelines for California rice growers using alternative water management strategies.

Concise General Summary of 2006 Results

- Changes in early season water management (usually related to weed control) are currently the greatest challenge for nutrient (particularly N) management in California rice systems. Many growers drain their fields early in the season which can lead to significant N losses when their fields are reflooded. The goal of this research was to quantify N losses as a result of a drain and understand the factors affecting N losses. From this we plan to (1) develop “tools” which growers can use to know the critical point when N losses are most likely to occur and (2) develop cost effective and efficient N recommendations for rice systems that use an early season drain.

- Two field studies were initiated in this initial year to evaluate the effect of early season water management on N dynamics. The first study was on two growers’ fields that were using a Clincher program (field drained for approximately 10 days for ground application). In this study we had two treatments: drained and undrained. Our results show that in the drained plots there was significant nitrate (25-35 lb N/ac) accumulation when during the drain period. In the undrained plots no nitrate accumulated. After the drained plots were reflooded the nitrate disappeared within 8 days due to either denitrification losses or plant uptake. Total N crop N uptake suggests that at least half and maybe more was lost. Also yields and N uptake were lower (on average, 340 lb/ac and 15 lbN/ac) in the drained treatments.

- An analysis of different rice establishment methods indicates that the yield potential of these systems is similar. This result is consistent with the two previous years of data. However, the amount of N required to achieve the yield potential varies between systems. As with the Clincher program, early season water management affects soil N availability early in the season. In these systems, flash-flooding to recruit weeds (in stale seedbed systems) or to germinate rice seeds (drill seeded system) can result in denitirfication losses.

- Data from these studies indicate that N management practices need to be revised in these systems in order to achieve optimal yields, and efficient cost effective fertilizer N use.

2006 Project Objective 1: To evaluate and quantify soil and fertilizer N losses as affected by early season water management in rice fields.

Many rice growers are beginning to change early season water management to facilitate the use of new herbicides and cultural weed control practices. One new approach requires a drain for the application of certain herbicides (i.e. “*Clincher*”). With this approach, growers may dry down their fields enough to support a vehicle and it may be up to three weeks between the time the field is drained and when it is reflooded. Similarly, some organic growers use deep flooding and lengthy dry-downs in the early season to shift weed pressures back and forth from water to dryland weeds with the intention of giving rice the competitive edge. Other methods being tested involve drill seeding and the use of a stale seed bed. Both of these methods require flushing the soil to induce rice or weed seed germination.

The wetting and drying of rice fields, a practice common to all of the above mentioned weed control strategies, changes the redox potential of soils. Fluctuations in redox potential can cause soil N to undergo transformations from one form to another. If not managed correctly, these transformations resulting from the wetting and drying of soil can lead to N losses.

In the first year of this study, our goal was to better understand N transformations in soil as a result of wetting, drying and rewetting cycles. Furthermore, we quantified 1) the amount of ammonium converted to nitrate during dry-down periods, and 2) the potential amount of nitrate being lossed as gas through denitrification following reflooding to an anaerobic state. To accomplish this objective we 1) conducted an experiment in two grower fields with an early season dry-down for a "*Clincher*" application and 2) conducted experiments at an experiment located at the Rice Experiment Station (RES) evaluating different rice establishment systems to control weeds. These systems have different early season water management practices.

On-Farm Study (Early season dry-down for Clincher):
The on-farm experiment was conducted in two fields utilizing a "*Clincher*" program west of Live Oak. They were managed by the same grower, and with the exception of straw management (one field had straw incorporated and the other had straw burned), all other practices were similar. The variety of rice grown was M-205, and a total of 159 lb N / acre was applied (105 lb N as aqua, 28 lb as liquid starter, 26 lb N as ammonium sulfate topdress).

There were two treatments (drained and undrained) per field, and each treatment was replicated three times in a completely randomized block design. The treatments were imposed in the fields by forcing 30" diameter metal rings 8" into the soil, while another 4" remained above the soil surface. The rings were forced deep enough to penetrate the heavy clay layer, creating a seal so water could effectively be kept in or out of the rings. Separate rings were used for different sampling periods. Each plot had both a ring for several mid-season samples and a ring for a final harvest sample (Fig. 1).

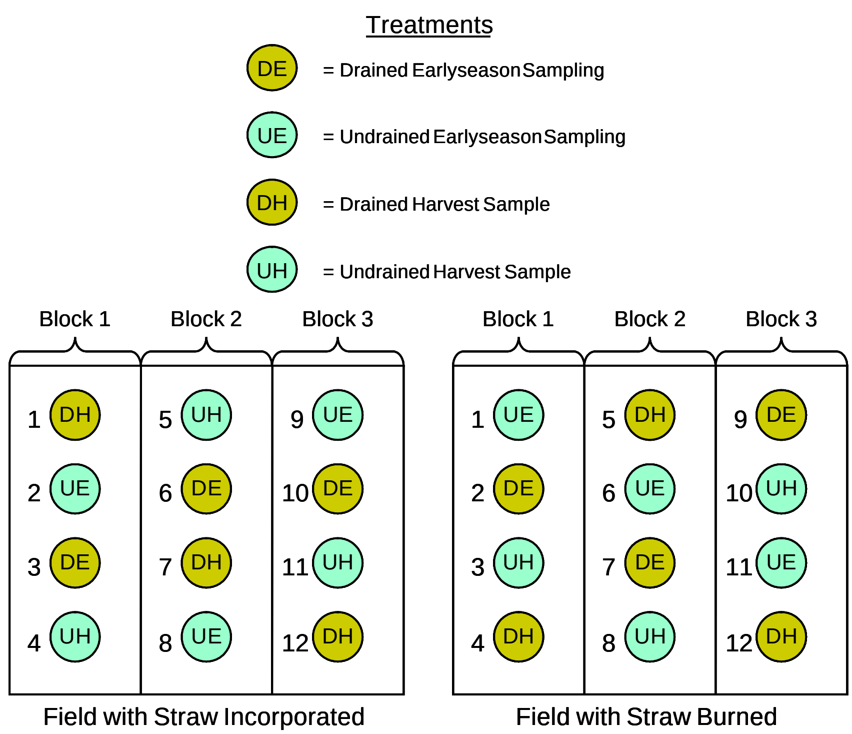

Figure 1. On-farm experimental design.

The "Drained" treatment was the standard farmer practice consisting of the draining of the field 2 weeks after seeding, a dry-down period followed by a "*Clincher*" application, and finally reflooding of the field. In the "Undrained" treatment, the flood water was maintained throughout the time the rest of the field was drained. The exception was that water from the Undrained treatment was quickly siphoned off just before "*Clincher*" was applied, and was then reflooded a couple hours thereafter, to avoid any experimental artifacts due to a difference in herbicide application or control of weeds.

In each set of plots, multiple soil and plant samples were taken. The soil samples were divided by two depths, 0-5 and 5-15 cm, to determine whether N concentrations were effected by early season drains differently by soil depth. The soil and plant sampling times were 1) just before the drain began, 2) just after the "*Clincher*" application, 3) at seven (soil only) days after reflooding, 4) at 20 days after reflooding, and 5) at harvest. In addition soil moisture, soil temperature, and redox potential were continuously monitored by wiring moisture and temperature sensors, and redox electrodes to data logging equipment in the field. This equipment was installed in the ring that was used for the harvest sample, since that ring was undisturbed throughout the entire season.

During the first few weeks of the season, total N in the burned field was about half that of the incorporated field (Fig. 2 and 3). In both fields the soil ammonium and nitrate decreased over the first month after which it remained low. Just before the drain for "*Clincher*" virtually all the available N was in ammonium form, and the majority of it was in the lower 5-15cm soil layer, suggesting that the N applied as aqua remained stationary at least until then. In the Undrained treatment no nitrate accumulated during the period of time the rest of the field was drained; however in the Drained treatment 35 lb N/ac in the straw incorporated field and 28 lb N/ac in the straw burned field accumulated as nitrate over the seven day drain period.

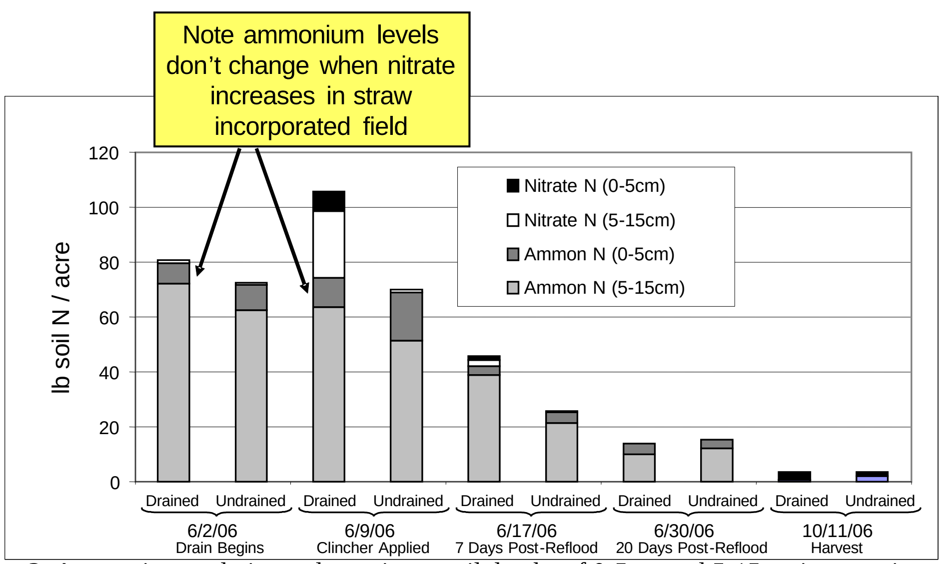

Figure 2. Ammonium and nitrate dynamics at soil depths of 0-5cm and 5-15cm in straw incorporated field.

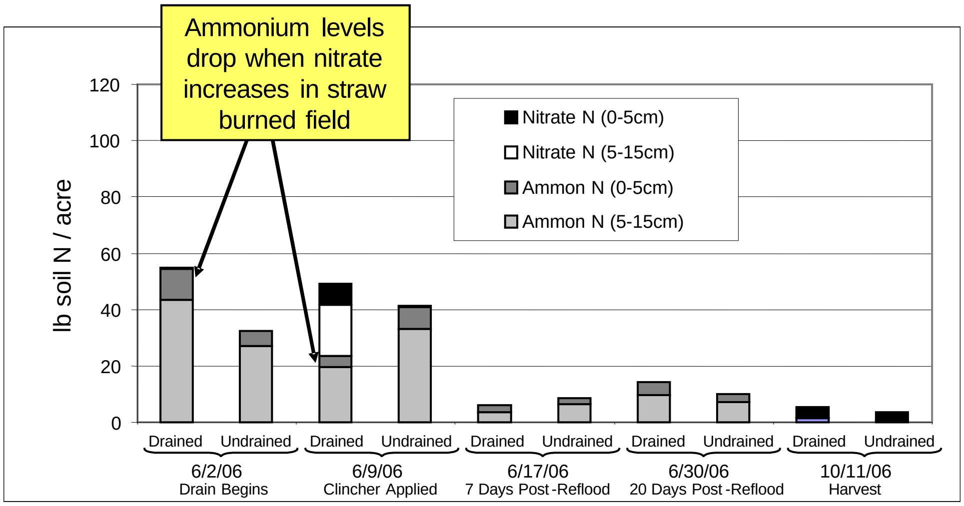

Figure 3. Ammonium and nitrate dynamics at soil depths of 0-5cm and 5-15cm in straw burned field.

Interestingly, in the straw incorporated field ammonium levels remained the same during the drain, despite the substantial increase in nitrate. Conversely, in the straw burned field ammonium levels dropped as nitrate levels increased. Though preliminary, this difference between fields suggests that during the drain the reoxygenation of soil may result in straw and soil organic matter N mineralization to ammonium.

When both fields were sampled seven days following reflooding, most of the nitrate that had accumulated in the Drained treatment was no longer present in the soil at either depth, and by twenty days after reflooding no nitrate could be accounted for at all. Though it is likely some of this depleted nitrate was taken up by the rice crop, there is reason to believe at least half (~15 lb N / acre) if not more of it was lost through denitrification. Directly measuring the quantity of nitrate lost through denitrification was beyond the scope of this experiment, however, we were able to indirectly estimate this quantity by comparing the difference in rice uptake of N between the Drained and Undrained treatments (Fig. 5).

Biomass accumulation and N uptake by rice were both similar between the Drained and Undrained treatments until the fields were reflooded following the "*Clincher*" application. By twenty days after reflooding, the Undrained treatment had higher biomass and higher N uptake than the Drained treatment, in both fields (figures 4 and 5). This crucial time period is when the rice crop goes into a very rapid growth phase, which is evidenced by the exponential biomass accumulation and N uptake curves, and the steeply declining soil mineral N curves. The N potentially lost through denitrification during this phase (figures 2 and 3) likely contributed to the early season lag in growth and N uptake observed in the Drained treatment.

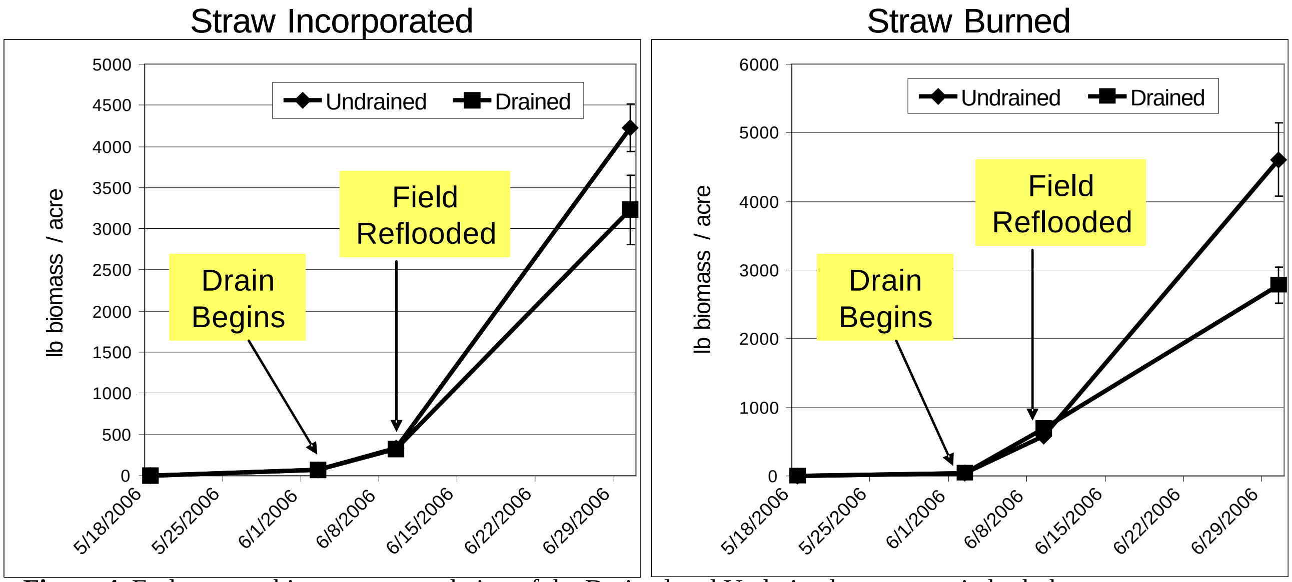

Figure 4. Early season biomass accumulation of the Drained and Undrained treatments in both the straw incorporated and burned fields.

The differences in early season N availability, crop growth and N uptake impacted yield and total N uptake. The effect the early season drain had on yield and total N uptake was largest in the straw burned field. When the two fields were averaged, the Undrained treatment had a 340 lb / acre yield and 15 lb N / acre uptake advantage over the Drained treatment. These data suggest an early season drain causes a buildup of soil nitrate with some subsequently lost with the reflood. This loss of nitrate may contribute to a yield loss and lower total N uptake by rice. A confounding factor that may have also contributed to the sluggish growth and reduced yield and N uptake observed in the Drained treatment may be the stress rice plants were subjected to during the draining period. It is also possible that both factors were responsible: rice plants were stressed at the same time as the nitrate began to disappear from the soil.

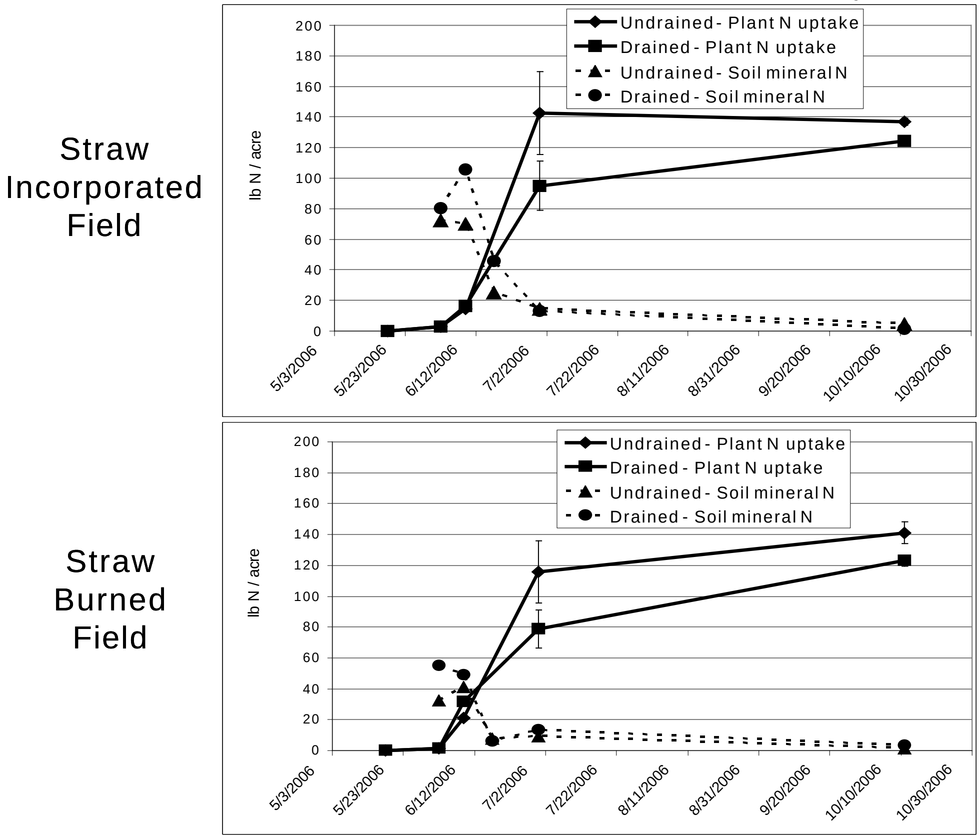

Figure 5. Rice uptake of N and depletion of total soil mineral N (ammonium and nitrate combined) between the Drained and Undrained treatments in both the straw incorporated and burned fields.

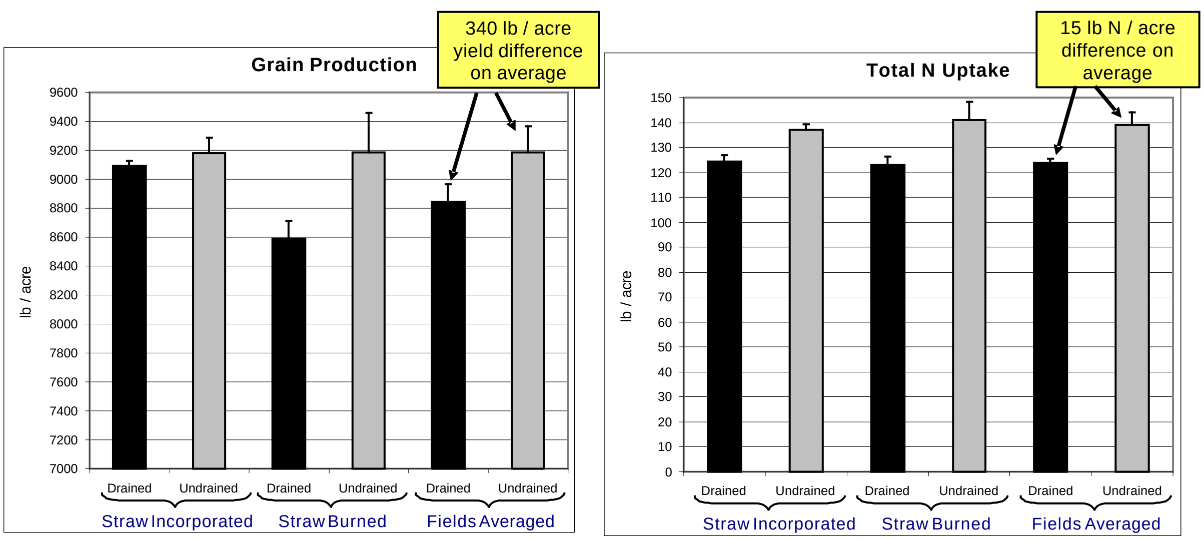

Figure 6. Yield and total N uptake at harvest of the Drained and Undrained treatments in the straw incorporated and burned fields. In addition, the two fields are displayed as an average (Fields Averaged).

The soil moisture, temperature, and redox potential data we collected using continuous data logging equipment have not yet been analyzed. Once analyzed, these data will be combined with the soil and plant N data discussed above to begin drawing correlations between N dynamics and these other measured variables.

Rice Experiment Station Alternative Stand Establishment Study:

Differences in early season water management are already present to varying degrees in the treatments at the RES alternative stand establishment study site. In this study we are evaluating combinations of drill seeding and stale seed beds on weed populations and weed control. We evaluated the effects of alternative crop establishment methods and early season water management on N cycling and N-use efficiency. There are five treatments in this study, and each is replicated four times. The treatments vary by seeding method, tillage, and weed management. Within each of the main treatment plots, an N rate trial was set up with N rates ranging from 0 to 200 lb N / acre (0, 100, 100 split application, 150 [main plot rate], and 200). This range enabled us to both calculate N-use efficiency and further fine tune the N management for each system.

Table 1. Treatment characteristics in RES alternative stand establishment study

Treatment / System	Tillage	Flash Flood for Weed Seed Germination	Water Seeding	Drill Seeding	Flash Flood for Rice Seed Germination
1	Conventional		X		
2	Conventional			X	X
3	Conventional	X	X		
4	No Spring Tillage	X	X		
5	No Spring Tillage	X		X	X

In three treatments (T1: water-seeded, conventional, T3 water-seeded, stale seedbed, spring till, T5 drill-seeded, stale seedbed, no-till). soil moisture and temperature sensors were installed at two depths. Soil samples (0-5cm and 5-15cm) were taken at pre-tillage; following tillage and land preparation; and just before and during every period of flooding or draining. In order to determine the effect of water management on N dynamics the soil N data (not yet complete) will be linked with soil moisture data from the two depths (Fig. 7).

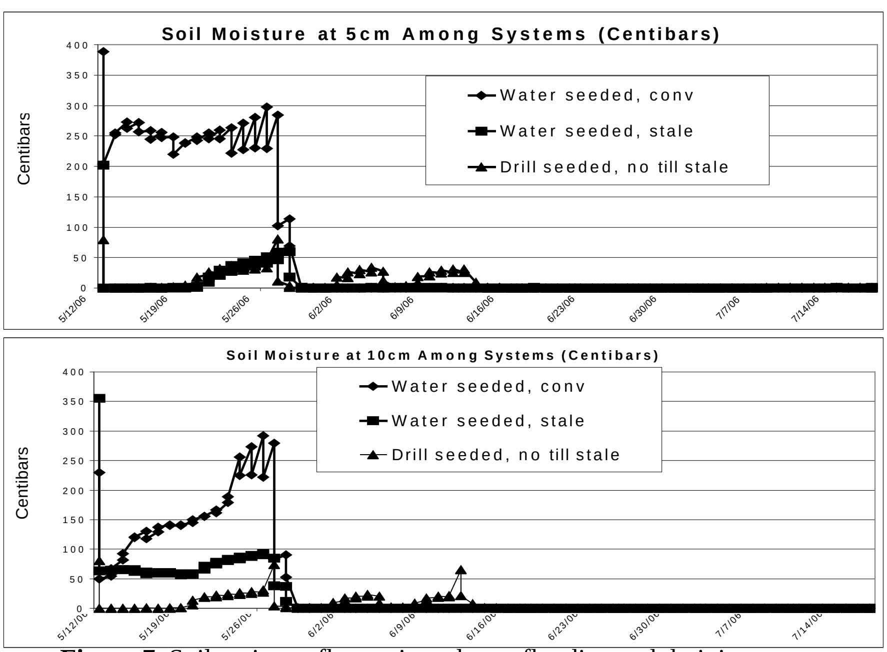

Figure 7. Soil moisture fluctuations due to flooding and draining events.

Main plot yields (all receiving 150 lb N/ac) varied among the different systems (Fig. 8). However, the yield potential for each system is similar but different rates of N are required to reach this potential (Fig. 9).

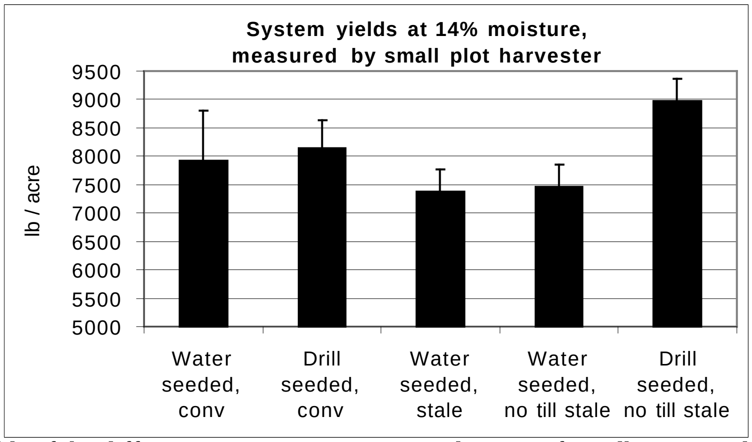

Figure 8. Yields of the different system treatments at and N rate of 150 lb / acre and at 14% moisture.

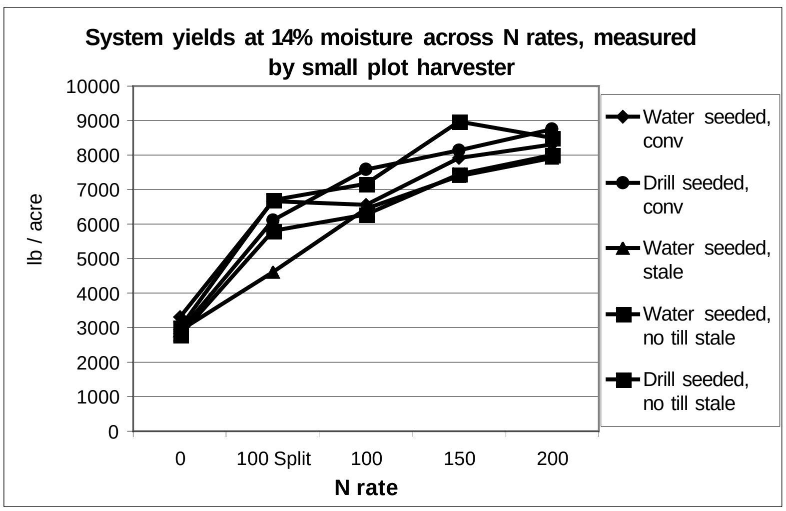

Figure 9. Yield response of the different system treatments from a range of 0-200 lb N / acre.

2006 Project Objective 2: To improve N fertilizer guidelines for California rice growers using alternative water management strategies.

The experiments were initiated in 2006 with the long term goal of developing improved N management strategies for growers using alternative early season water management strategies. In this initial year we began to investigate the effect of wetting and drying on N cycling and rice production. The results are encouraging but, based on a single year of data we can not make solid recommendations Never the less, we have identified that early season drainage (both for "*Clincher*" or crop establishment) can result in nitrate buildup during the drain periods which is susceptible to loss when fields are flooded. As such, efficient N management practices for these systems need to be developed and this will be the focus of on-going research.

Our results are both relevant and of interest to rice growers and PCA's and preliminary results from this years study have been presented at a number of meetings already this year (see below) and will be presented at the upcoming winter grower meetings.

Publications, Reports, and Presentations

Koffler, K., B. Linquist, L.F.T da Silva, C. Mutters, C. Greer, and C. van Kessel. 2006. Linking changes in early season water management to changes in nitrogen dynamics in California rice systems. Rice Field Day. Rice Experiment Station. Biggs, CA.

Koffler, K., B. Linquist, L.F.T. da Silva, C. Mutters, C. Greer, and C. van Kessel. Nitrogen dynamics in rice systems as affected by an early season drain. Oral presentation at Northern California Chapter of California Association of Pest Control Advisors, 2006 Fall CE Meeting. Ord Bend Community Hall, Ord Bend, CA.

Linquist, B, Koffler, K., Mutters, C. Greer, and van Kessel, C. 2006. An Overview of rice nutrition. Oral presentation for UCCE/CAPCA Plant Nutrition/Soil Fertility Meeting, December 5, 2006, Yuba City, CA.