COMPREHENSIVE RICE RESEARCH

ANNUAL REPORT
(January 1, 2009 - December 31, 2009)

PROJECT TITLE: Scaling out Alternative Rice Establishment Practices to Control Herbicide Resistant Weeds

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OBJECTIVES OF PROPOSED RESEARCH:

1. Test the performance of these systems at a grower field scale and identify the key constraints to management at this scale.

2. Identify the ability of these systems to control herbicide resistant weeds across a range of management practices, soils and climates.

3. Identify appropriate nutrient management practices for these systems based on results from different soils in the Sacramento Valley region.

4. Develop and disseminate best management practices for these systems.

OBJECTIVE 1. *Test the performance of these systems at a grower field scale and identify the key constraints to management at this scale.*

Select alternative stand establishment systems tested over four years at the Rice Experiment Station (RES) at Biggs, California were tested in grower/cooperator fields around the Sacramento Valley to determine the feasibility of scaling these systems from relatively small acreage to full scale rice production. The majority of these involved the spring tilled stale seedbed technique where the field is conventionally tilled and rolled in the spring. Following this, the field is subjected to pre-plant irrigation by flushing for a period of time necessary to get sufficient germination of the weeds deemed to be the most significant deterrent to satisfactory yields. This pre-plant irrigation is aimed at encouraging germination of watergrass (incl. “mimic”), barnyardgrass, sprangletop and smallflower umbrellasedge. Late season germinating weeds, or those requiring longer and near anaerobic flooding situations for germination, were not targeted by this technique to avoid a prolonged delay in planting rice. Once a substantial flush of weed emergence has been achieved, an application of a total, non selective, herbicide was made. The herbicide used in these cases was glyphosate, which provides control of all herbicide-resistant weed biotypes that can infest rice fields in California. One spring tilled stale seedbed implemented in 2008 in the Glenn County farm, followed this same technique and achieved excellent grass control. This season, the field was doubled in size by elimination of a road. The portion of the field where the technique was used in 2008 had far fewer grasses germinate with the flushing technique, demonstrating the ability of the stale seedbed technique to reduce weed seed bank of targeted species. By midsummer, the control of watergrass achieved in 2009 was in the low 90% range, while control of sprangletop was nearly 100% (Table 1). Highest yields in a test plot set up within this same field were in the 8,000 to 9,800 lb/acre range when the pre-plant application (stale seedbed) of glyphosate was followed at the three leaf stage of rice by either Super Wham (4484 g ai/ha), Granite SC (35 g ai/ha) or Regiment (44.5 g ai/ha) plus UAN (2% v/v). The untreated control yielded 2,000 lb/acre and plots with glyphosate alone yielded an average of 7,800 lb/acre. Grower’s yields in the stale-seedbed treated field ranged from 7,200 to 8,200 lb/acre. This is compared to an adjoining area in a conventional field where herbicide treatments were skipped and that yielded 4,600lb/a.

Table 1. Stale seedbed - resistant site

Treatment	Rate		Timing[2]	Date		Weed Control[1] ECHPH	LEEFA	SCPMU	CYPDI	Yield/Acre (14%)
	(g ai/ha)	Prod./a				6-Aug				24-Sep
Untreated[3]						9	26	2	4	2025
Roundup + UAN	v/v + 2% v/v	1.2lb a.e. + 2% v/v	After flush	28-May		92	97	63	100	7811
Roundup + UAN fb. Super Wham + COC	2% v/v + 2% v/v fb. 4484 + 1.25% v/v	1.2lb a.e. + 2% v/v fb. 4qt + 1.25% v/v	After flush fb. 3-4lsr	28-May	6-Jul	93	99	92	100	10017
Roundup + UAN fb. Granite SC + COC	2% v/v + 2% UAN fb. 35 + 2.5% v/v	1.2lb a.e. + 2% v/v fb. 2oz + 2.5% v/v	After flush fb. 3-4lsr	28-May	6-Jul	90	100	63	100	9461
Roundup + UAN fb. Granite SC + Clincher + COC	2% v/v + 2% UAN fb. 35 + 315 + 2.5% v/v	1.2lb a.e. + 2% v/v fb. 2oz + 15oz + 2.5% v/v	After flush fb. 3-4lsr	28-May	6-Jul	90	98	88	100	8396
Roundup + UAN fb. Regiment + NIS + UAN	2% v/v + 2% v/v fb. 44.5 + 0.25% v/v + 2.0% v/v	1.2lb a.e. + 2% v/v fb. 0.79oz + 0.25% v/v + 2.0% v/v	After flush fb. 3-4lsr	28-May	6-Jul	88	99	50	79	9201
LSD (P=0.05)										1480

[1] ECHPH (Late watergrass), SCPMU (Rice field bulrush), CYPDI (Small flower Umbrellaplant), HETLI (Duck salad), LEFFA (Sprangletop), BAORO (Waterhyssop), AMMCO (Redstem); SAGMO (California arrowhead); MOOVA (Monochoria)

[2] fb. (followed by), lsr (leaf stage of rice), Til (tillers of rice), PFS (pre-flood surface), PPI (pre-plant incorporated).

[3] Untreated weed control values represent % cover by the respective weed species

Trial Information

1. Trial timeline
Spring tilled and rolled
May 3 Flood field and hold shallow water to keep soil wet
May 20 Begin drain of field
May 28 Plots layed out in an area of the field where there was an even stand of weeds and stale seedbed treatments applied
May 29 main field sprayed with 2% glyphosate using ground rig
June 2 field flooded
June 4 Seed applied at 180lb/a, M104
June 9 ammonium sulfate applied at 158 units of N/a
July 3 Drain field
July 6 follow up treatments applied to test plots
July 9 Apply 2oz/a Granite SC to main field, forgot to add crop oil
July 10 applied 6lb ai/a propanil to main field
July 12 Flood field
July 20 applied Quadris
2. Trial managed as a stale seedbed with pinpoint drain for foliar herbicide applications.
3. Watergrass and sprangletop were 2-3 leaf, bulrush was 1-2 leaf, smallflower ws 1-2 leaf, ducksalad was 1-2 leaf on May 28.
Watergrass was 3 tiller, sprangletop was headed, smallflower was flowering, ducksalad was early flower, redstem 5 leaf on July 6.
4. Spray applications made with 20 gallons/acre using 8003 nozzles.
5. Weather conditions on May 28: Air temperature 92^{o} F, wind 0-2 MPH from the southwest.
Weather conditions on July 6: Air temperature 84^{o} F, wind 1-2 MPH from the east.

The fall tilled, no spring tilled field at the same farm was also subject to a stale seedbed treatment was flushed for weed establishment, but not as many rice weeds emerged. Stand establishment was not as good as in the spring tilled field. Grower yields for this treatment ranged from 4,300 to 5,600 lb/acre. An adjoining field with a conventional herbicide program had yields from 7,200 to 9,000 lb/acre. Poor stand establishment and yield in a portion of the stale seedbed field may be associated with old gas test wells that may not have been capped off sufficiently. The grower has stated that rice stands and yield have been poor in this field, but results have not been as evident until implementation of a yield monitor on his combine this season.

Two other grower/cooperators utilizing the spring tilled stale seedbed method had similar results in control of grasses and sedges. Further description of the methods and results at these sites will be reported by other researchers.

Key constraints to implementation of these stand establishment systems are reduced growing season potential due to delay in planting, which together with the need for further adjustments to the fertilization regime may have been responsible for the slight to moderate yield reduction observed. Lower yields had not been an issue during the 5 years of experimentation at the Rice Experiment Station.

OBJECTIVE 2. *Identify the ability of these systems to control herbicide resistant weeds across a range of management practices, soils and climates.*

All treated fields mentioned in objective 1 have known resistant late watergrass (mimic). The stale seedbed treatment for germination of weeds was successful in getting the majority of resistant grass in the germination zone to establish and be subsequently killed by the glyphosate application. These sites were located on different soil types in different portions of the rice growing region of California and managed by different farmers. Even though there were only four locations where these systems were tested by a grower, it is encouraging that there were no complete failures when the spring tilled stale seedbed was implemented.

OBJECTIVE 3. *Identify appropriate nutrient management practices for these systems based on results from different soils in the Sacramento Valley region.*

Previous research at the RES has indicated that alternative establishment systems may require more nitrogen (N) to achieve maximum grain yields compared to conventional systems. The defining aspect of alternative systems is a stale seedbed approach, where fields are flooded and drained prior to planting to encourage weed germination for subsequent herbicide treatment. This practice is usually coupled with zero spring tillage to minimize disturbance of the soil after the stale seedbed has been implemented, ensuring that remaining weed seeds are not brought to the soil surface. Urea is commonly used as a source of fertilizer N in these systems since aqua ammonia applications may sufficiently disturb the seedbed and promote further weed germination. As a result, alternative establishment techniques require changes in pre-season water management, tillage, and N application practices which may affect the efficiency of applied N in these systems. To address this issue and develop improved nitrogen management guidelines for alternative establishment systems, nitrogen fertility trials were implemented in 2008 and 2009 at the Rice Experiment Station (RES) and a total of five on-farm sites. The results from the 2009 growing season are presented below.

This year we conducted N fertility trials at the RES Systems Project and three on-farm sites. At the RES, the main plot treatments consisted of wet seeded conventional, wet seeded no-till stale seedbed, and drill seeded no-till stale seedbed systems. The three on-farm N fertility experiments were all conducted in fields testing alternative stale seedbed systems under grower management practices. This research builds upon results from previous N fertility trials conducted in alternative systems at the RES beginning in 2004. For the past two years at the RES, N fertility trials were established using a split-plot randomized complete block design in which establishment systems were main plots and N treatments were sub-plots. N fertility trials at on-farm sites were implemented using randomized complete block designs consisting of the same nine N treatments. All N treatments were replicated four times at each location. Total N application rates in the sub-plots ranged from 0-200 lb N ac^{-1} in the form of urea. Several growers have expressed interest in using ammonium sulfate in these systems, so an ammonium sulfate treatment of 100 lb N ac^{-1} was also included. Several N treatments were split between preflood and mid-tillering to determine if split applications would result in increased yields and nitrogen use efficiencies as seen in previous studies. The remaining N treatments were all applied prior to the permanent flood (Table 2).

Table 2. The source, rate, and timing of nitrogen treatments.

Treatment #	N source	Total N Rate (lb/ac)	Amount Applied Preflood (lb/ac)	Amount Applied Mid-tillering (lb/ac)
1	Urea	0	0	0
2	Urea	100	100	0
3	Urea	100	25	75
4	Urea	100	75	25
5	Urea	150	150	0
6	Urea	150	112.5	37.5
7	Urea	200	200	0
8	Urea	200	150	50
9	Ammonium sulfate	100	100	0

Rice Experiment Station

This season marked the final year of the Alternative Systems project at the RES and consequently much of our sampling occurred at this site. Our objectives for the N fertility experiments at the RES were to (i) determine the impacts of early season flushes on native soil N dynamics and quantify N losses that may be occurring during the flood, drain, re-flood periods, (ii) quantify the speed of early season plant growth and canopy closure in alternative systems to further assess competitiveness with weeds, (iii) determine early season N uptake values to gauge soil and fertilizer N availability, and (iv) determine the optimum rate, timing, and source of N fertilizer applications to maximize grain yields in alternative systems. N fertility plots were visually monitored and soil and plant samples were obtained throughout the growing season. Intensive soil sampling occurred during field preparation stages, canopy cover measurements were made prior to PI, early season N uptake values were determined at mid-tillering and PI, and aboveground biomass was harvested in early to mid October. The results presented below are from data collected during the growing season. Harvest samples are still being processed for the RES N fertility trials. Grain yields and total N content of harvested straw and grain will subsequently be determined in order to calculate nitrogen use efficiencies for each system.

Soil Nitrogen Dynamics

Trends in mineral soil N concentrations were determined to identify management factors driving mineralization and nitrification processes in stale seedbed and conventional systems, as well as quantify N losses and soil N availability during critical growth periods. To examine soil N dynamics in relation to pre-season flushes, rice soils were sampled to a depth of 15 cm in zero N plots before and after flooding events. Soil samples were placed on ice and analyzed for ammonium and nitrate concentrations within 36 hrs. Native soil N values for the main plot replicates were averaged for each sampling date over a three month period, which included field preparation and early season growth (Figures 1 and 2).

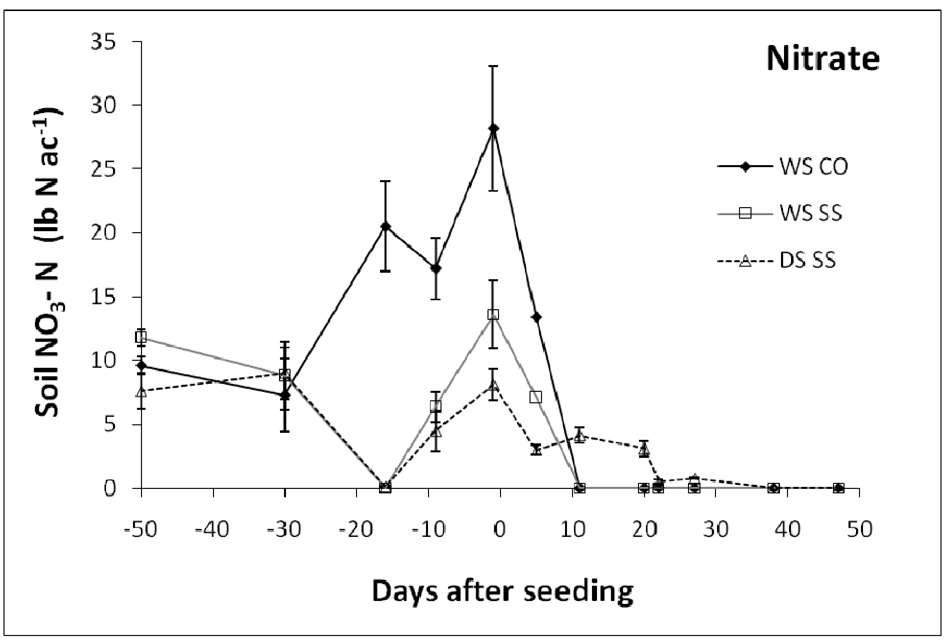

Figure 1. Soil nitrate concentrations for zero N plots in each establishment system during field preparation activities and early season growth. Tillage

occurred in conventional plots at day -45, the pre-season flush occurred in stale seedbed plots between days -30 and -10, and the permanent flood occurred at day 0 in water seeded plots and day 28 in drill seeded plots.

Initially, stale seedbed systems were expected to incur greater N losses due to pre-season flushes, which were thought to stimulate nitrification and subsequent denitrification when the field was re-flooded for planting. However, the nitrate content of stale seedbed plots remained relatively low compared to conventional plots after the first flush (day -30 to -10) and at planting time (day 0). It is likely that spring tillage in conventional systems stimulated greater nitrification, possibly due to increased aeration and warmer soil temperatures. This resulted in the accumulation of nearly 30 lb N ac^{-1} of soil nitrate by planting time (Figure 1). Conversely, the drill seeded and water seeded stale seedbeds accumulated approximately 8 and 14 lb N ac^{-1} of soil nitrate, respectively, by planting time. At day 0, the permanent flood occurred in water seeded systems which presumably resulted in denitrification of soil nitrate, as nitrate concentrations dropped to zero within ten days and rice seedlings were too small to account for this N uptake.

The drill seeded system received weekly flushes for the first month after seeding to facilitate stand establishment. Hence, the soil remained saturated below the top few cm of the soil surface and soil nitrate concentrations remained relatively low at 3-5 lb N ac^{-1} (Figure 1). Drill seeded soil nitrate levels, consistent with water seeded systems, dropped to zero within a week after the permanent flood which occurred one month after seeding. Interestingly, total pre-season N losses due to denitrification were greatest in conventional plots. Although stale seedbed plots experienced two flooding events which both contributed to pre-season nitrate losses, both of these systems each lost approximately 20 lb N ac^{-1} of nitrate in total, while conventional systems lost close to 30 lb N ac^{-1}. These results suggest that pre-season N losses resulting from flushes do not account for the higher N requirements of alternative establishment systems.

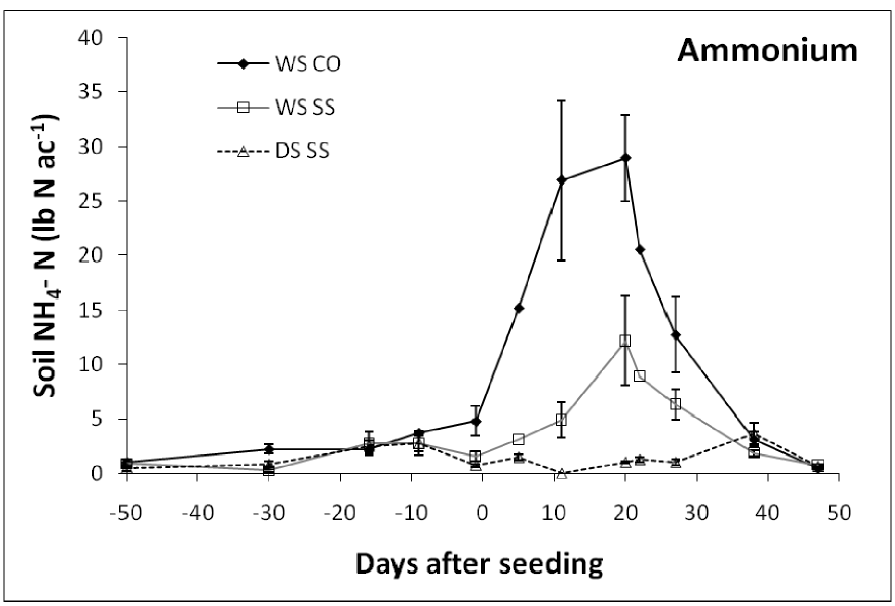

Figure 2. Soil ammonium concentrations for zero N plots in each establishment system during field preparation activities and early season growth. Tillage occurred in the conventional plots at day -45, the pre-season flush occurred in stale seedbed plots between day -30 and -10, and the permanent flood occurred at day 0 in water seeded plots and day 28 in drill seeded plots.

Soil ammonium concentrations were also determined for this period (Figure 2). Ammonium concentrations remained relatively low in all systems during pre-season flushes and tillage events, with maximum values approaching 6 lb N ac^{-1} occurring in conventional plots. Low soil ammonium values prior to planting suggest that slightly aerobic soil conditions in the stale seedbed, and fully aerobic conditions in the conventional plots, may have favored nitrification processes. Interestingly, soil N mineralization occurred more rapidly in all systems after the permanent flood. Tillage in conventional systems appears to have contributed to a significant increase in soil N mineralization, with conventional systems exhibiting greater ammonium concentrations than wet seeded stale seedbed systems at day 20 (nearly 30 lb N ac^{-1} compared to 12 lb N ac^{-1}). Although delayed, the drill seeded system also exhibited an increase in soil N mineralization once the permanent flood occurred at day 30, but at a reduced rate compared to the other two systems (Figure 2). Rice plants began to rapidly utilize soil mineral N around mid-tillering in all three systems, causing ammonium levels to drop close to zero by day 50. Contrary to nitrate N losses, these results may partially explain the larger N requirement for stale seedbed systems as there appears to be less mineral soil N available for early season plant growth in stale seedbed compared to conventional systems.

Canopy closure

Early season crop growth rate and canopy closure was assessed in each system prior to PI. A line quantum sensor was used to quantify the amount of light penetrating the canopy in treatment plots receiving 150 lb N ac^{-1} in each system (Figure 3). This tool represents an indirect measurement of crop growth rates and biomass accumulation. The incident radiation was measured at 1 m above the canopy and the intercepted radiation was determined by ten random measurements taken below the canopy in each plot. The sensor was held a standard six inches above the soil surface for all below-canopy measurements.

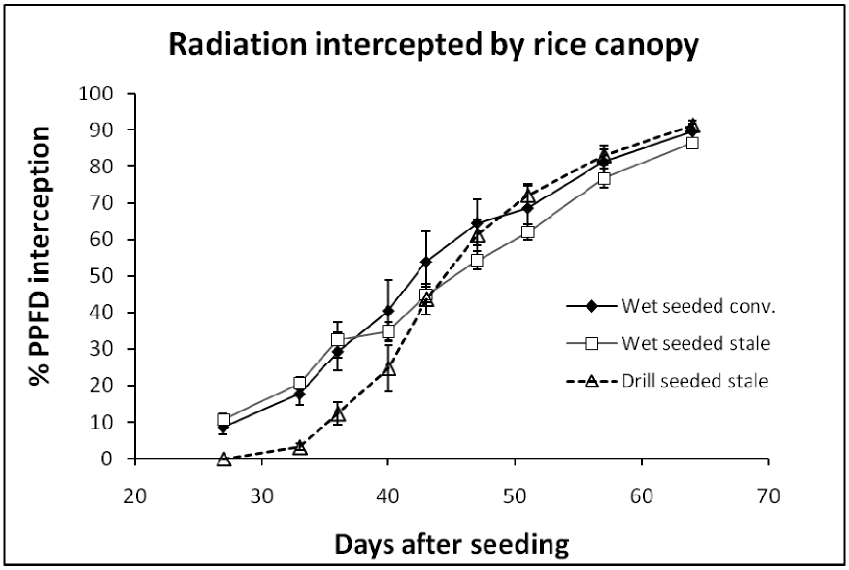

Figure 3. Incident radiation (measured as PPFD) intercepted by the rice canopy at early stages of plant growth. Nitrogen applications (150 lb N ac^{-1}) occurred prior to the permanent flood, which was day 0 in water seeded plots and day 28 in drill seeded plots.

Contrary to visual observations in previous seasons, there were no significant differences in the rate of canopy closure or the amount of light intercepted at any sampling date between wet seeded systems (Figure 3). However, the drill-seeded stale seedbed system intercepted significantly less light during each of the first three sampling dates. This is most likely because it received N later than the other two systems (around one month after seeding). After N was applied and the permanent flood was brought on, the drill seeded system grew rapidly and actually surpassed the wet seeded systems with respect to % PPFD interception. At the final sampling date near PI, the drill seeded system intercepted significantly more light compared to the wet seeded stale seedbed system, which may again be related to water management practices. Repeated flushes during the first month of growth in drill seeded plots caused larger root systems to develop, which may have facilitated more efficient N uptake and biomass accumulation once the N fertilizer was applied around day 30. These results may also reflect the native soil N availability of each system. The drill seeded and conventional both had consistently higher light interception values than the wet seeded stale seedbed, despite all three systems receiving the same amount of applied N. As discussed previously, this may be related to lower N mineralization rates and decreased soil N availability in wet seeded stale seedbed systems.

N uptake at Panicle Initiation

All N fertility treatment plots were sampled at PI to determine N uptake values and assess soil and fertilizer N availability during early season growth periods (Figure 4). There was a significant interaction between establishment systems and N treatments, indicating that each system responded differently to N fertilizer rates. Rates of 100 and 150 lb N ac^{-1} resulted in similar N uptake values in the conventional and drill seeded stale seedbed systems, while rice responded more positively to 150 lb N ac^{-1} compared to 100 lb N ac^{-1} in the wet seeded stale seedbed system (Figure 4). In general, the results show that higher N application rates of 150 and 200 lb N ac^{-1} resulted in significantly higher biomass and N uptake values compared to 100 lb N ac^{-1} treatments across systems (Table 2). Split N applications tended to produce higher N uptake values than preflood N applications within the same N rate (Figure 4). The observed N response in each system suggests that rice plants tend to utilize much of the available N supplied by fertilizer. However, it is possible that high N uptake rates mainly benefit biomass production and may not translate into increased grain yields at harvest. If this is the case, high N rates may be related to luxury N uptake which is to be avoided in order to maximize the N use efficiency of these systems. It is notable that the 150-50 lb N ac^{-1} treatment in the drill seeded system did not produce the biomass and N uptake response to high N rates as it did in both wet seeded systems. This may be a result of the initial N application occurring one month later in drill seeded systems. These results imply that the majority of N must be applied well before PI in order to maximize N uptake and early season biomass production.

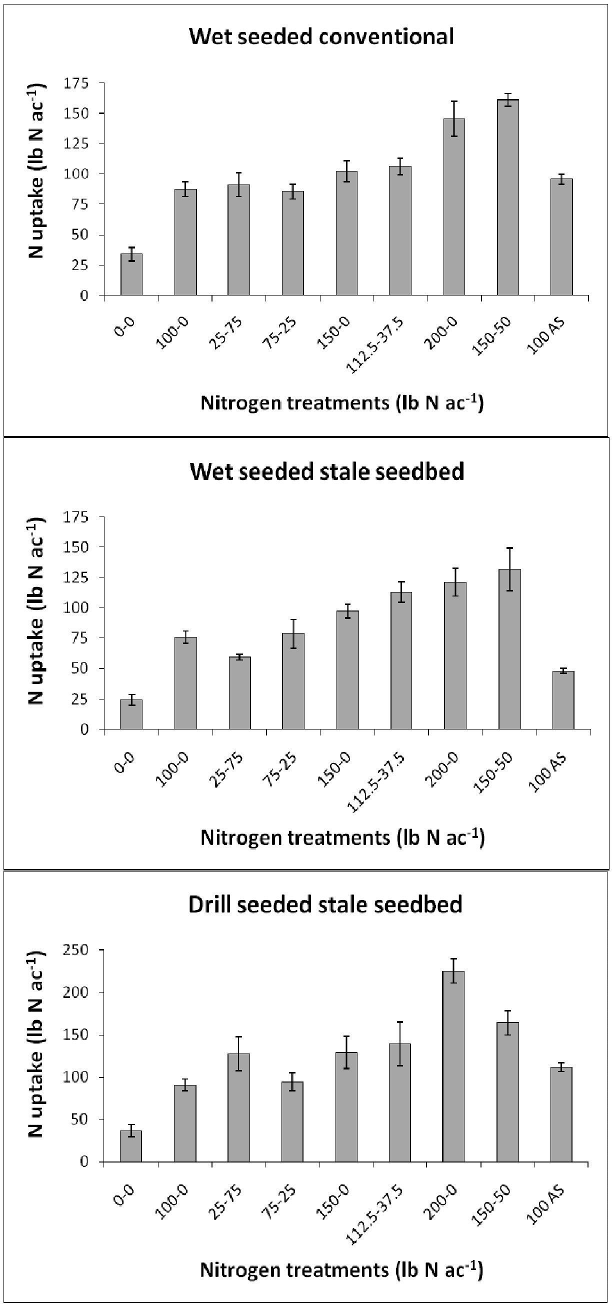

Figure 4. N uptake values for RES N fertility trials at PI. Error bars represent +/- the standard error of four replicates.

N uptake results for lower N rates, including the four 100 lb N ac^{-1} treatments, varied across systems. For example, the 25-75 lb N ac^{-1} split treatment exhibited N uptake values similar to the preflood 100 lb N ac^{-1} in the conventional system, but significantly lower biomass and N uptake values than the 100 lb N ac^{-1} treatment in wet seeded stale seedbed systems (Table 3). This may be due to lower native soil N mineralization occurring in the stale seedbed systems. Therefore, at a preflood N rate of 25 lb N ac^{-1}, total soil N plus fertilizer N availability may not be adequate to sufficiently meet early season crop N needs in stale seedbed systems. However, the 25-75 lb N ac^{-1} treatment produced significantly higher yields than the 100 lb N ac^{-1} treatment in the drill seeded system. This may be related to the fact that the first portion of this specific split N treatment (25 lb N ac^{-1}) was applied before seeding, while the remaining drill seeded N treatments were applied either prior to the permanent flood (one month after seeding) or split between the permanent flood and mid-tillering. Despite the delayed N application date in drill seeded systems, the highest N uptake values of any system occurred in the 200 lb N ac^{-1} drill seeded treatment (Figure 4). Ammonium sulfate treatments performed well compared to other 100 lb N ac^{-1} treatments, except in the wet seeded stale seedbed system which has consistently exhibited a poor response to ammonium sulfate N treatments.

Table 3. Biomass and N uptake values for RES N fertility trials at PI. Means followed by the same letter are not significantly different from each other (LSD, $p < .05$).

	RES Biomass and N uptake at PI					
N trt	**WSCO**	**WSSS**	**DSSS**	**WSCO**	**WSSS**	**DSSS**
	Biomass, lb ac^{-1}			N uptake, lb N ac^{-1}		
0	3407 d	2674 d	3552 d	34 d	24 e	37 e
100	6408 bc	5584 b	6138 c	88 c	76 c	91 d
25-75	5553 c	4024 c	6891 abc	91 bc	59 d	128 bcd
75-25	5971 c	5645 b	6044 c	86 c	79 c	94 d
150	6259 bc	6237 ab	6772 abc	102 bc	97 b	129 bcd
112.5-37.5	6060 c	6894 a	6432 bc	106 b	113 ab	139 bc
200	6945 ab	5932 ab	7658 a	146 a	121 ab	225 a
150-50	7609 a	6616 ab	7242 ab	161 a	132 a	165 b
100 AS	6336 bc	4577 c	6425 bc	96 bc	48 d	112 cd

On-farm N fertility Trials

We collaborated with three growers this season who were testing out alternative rice establishment practices at the field scale. N fertility trials were implemented using nine N treatments in a randomized complete block design with four replications at each site (Table 1). The on-farm sites were located near Willows, Williams, and Maxwell. Each grower implemented a stale seedbed prior to the permanent flood (fields were flushed and sprayed with glyphosate once a sufficient amount of weeds had germinated). Two sites received no spring tillage, but spring tillage did occur prior to the stale seedbed flush at the Maxwell site. All three sites were water seeded. N treatments were applied to the soil surface the day prior to the permanent flood. For split N applications, the second N portion was applied at mid-tillering. Since the majority of plant and soil sampling occurred at the RES this season, grower sites were visually monitored during the season and harvested at physiological maturity. Grain yields are reported below (Figures 5,6, and 7). Total N uptake values for grain and straw portions are still being determined. Zero N plots will be used as a measure of soil N availability to calculate N recovery efficiencies.

Nitrogen applications significantly increased grain yields at all on-farm sites. However, each site responded differently to N fertilizer rates. The Willows and Williams sites continued to respond to N rates up to 200 lb N ac^{-1} (Figures 6 and 7) while the Maxwell site reached maximum yields around 100 lb N ac^{-1} (Figure 8). N response curves were constructed for each site by grouping grain yield results by total N applied (100,150, or 200 lb N ac^{-1}). Preflood, split, and ammonium sulfate treatments are labeled for each N rate. The split 75-25 lb N ac^{-1} treatments had significantly higher yields than the 25-75 lb N ac^{-1} across sites (Table 4). This may be a result of low native soil N mineralization and availability in minimum tillage systems, similar to what was observed with native soil N dynamics at the RES. Zero N grain yields were comparable at the Willows and Williams sites, but tended to be higher at the Maxwell site (Figure 8). Higher soil N contributions could possibly explain the lower N response at the Maxwell site.

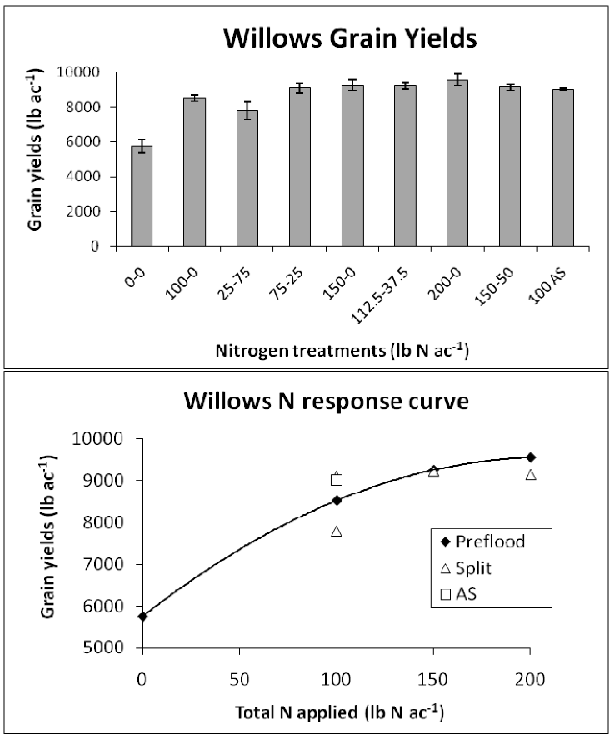

Figure 5. Grain yields (adjusted to 14% moisture) and N response curve for on-farm research site near Willows. Error bars represent +/- the standard error of four replicates.

Grain yields at the Willows site support results obtained at the RES in years past. The stale seedbed system continued to respond to N rates up to 200 lb N ac^{-1}, with the highest yields occurring for preflood compared to split N applications within each N rate (Figure 5). The split 150-50 lb N ac^{-1} treatment produced lower yields than the 200 lb N ac^{-1} preflood treatment, which suggests that early season N requirements were not completely met when the second N portion was applied at mid-tillering. Interestingly, the ammonium sulfate appeared to perform better at this site than the RES, possibly because of a higher soil pH.

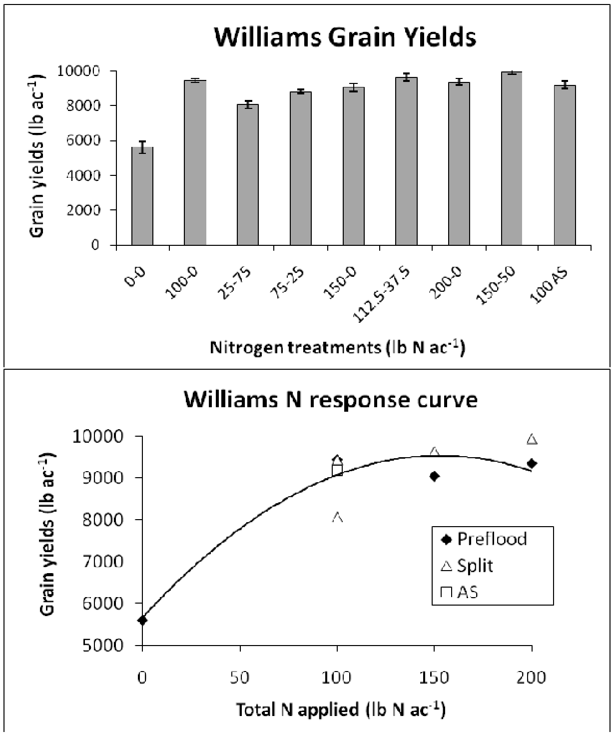

Figure 6. Grain yields (adjusted to 14% moisture) and N response curve for on-farm research site near Williams. Error bars represent +/- the standard error of four replicates.

The site located near Williams exhibited similar trends in grain yields. This stale seedbed system also continued to respond to N rates up to 200 lb N ac^{-1}, but split N applications produced higher yields than preflood N applications within the same N rate (Figure 6). The ammonium sulfate treatment did not produce yields significantly different than other 100 lb N ac^{-1}, except for the 25-75 lb N ac^{-1} treatment which had the lowest yields at this N rate (Table 4). The preflood 100 lb N ac^{-1} treatment had higher yields than the preflood 150 lb N ac^{-1} treatment.

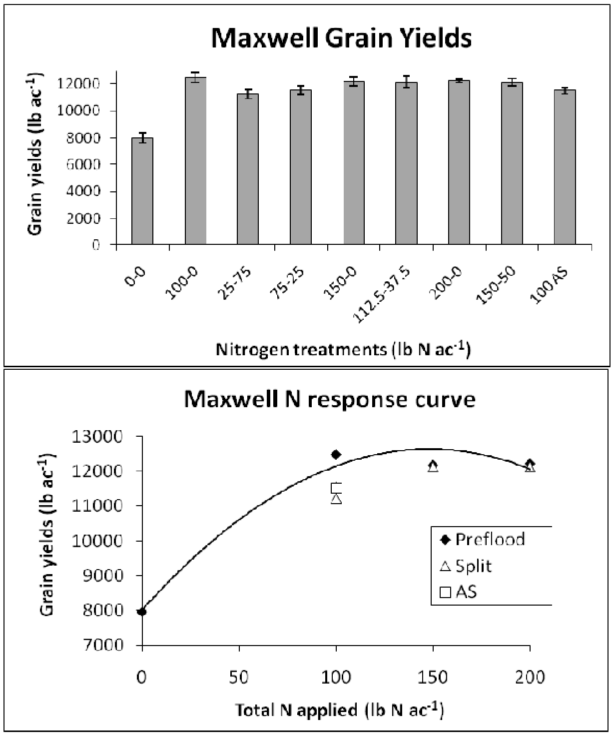

Figure 7. Grain yields (adjusted to 14% moisture) and N response curve for on-farm research site near Maxwell. Error bars represent +/- the standard error of four replicates.

Grain yields at the Maxwell site demonstrated less of an N response than the other two sites (Figure 7). One possible explanation for this is that spring tillage occurred at this site and not the other two sites, suggesting that higher zero N grain yields may be related to higher native soil N availability. This would reduce the need for applied N fertilizer and relatively higher yields could be achieved at lower N rates, as characterized by the comparable yields for this site at 100, 150, and 200 lb N ac^{-1} (Table 4). In this system, preflood N treatments performed quite similar to split N treatments, except at the 100 lb N ac^{-1} rate. Yields remained relatively steady above 100 lb N ac^{-1} for preflood N treatments, suggesting that higher N rates may not be required in stale seedbed systems when coupled with conventional spring tillage. However, the effects of tillage were not specifically examined in this experiment and further research is necessary to investigate the contributions of soil N with respect to tillage.

Table 4. Grain yields for on-farm N fertility trials, with yields adjusted to 14% moisture. Means followed by the same letter are not significantly different from each other (LSD, $p < .05$).

	Grain yields for on-farm sites		
N trt	**Willows**	**Williams**	**Maxwell**
	----------	lb ac^{-1}	----------
0	5750 d	5601 e	7969 c
100	8518 bc	9442 ab	12494 a
25-75	7786 c	8055 d	11234 b

75-25	9093 ab	8791 c	11559 ab
150	9250 ab	9051 bc	12187 ab
112.5-37.5	9220 ab	9641 ab	12141 ab
200	9549 a	9352 abc	12235 ab
150-50	9138 ab	9950 a	12141 ab
100 AS	9009 ab	9187 bc	11515 ab

Summary and Conclusions

Herbicide-resistant weeds represent a considerable management challenge for California rice growers. Alternative rice establishment techniques that integrate cultural and chemical weed control practices have been developed to provide growers with tools to effectively manage herbicide-resistant weed populations. The objectives of this study were to determine the optimum rate, timing, and source of N fertilizer applications to maximize grain yields for minimum tillage, stale seedbed rice establishment systems.

Nitrogen fertility trials were conducted over a two year period (2008-2009) at the Rice Experiment Station and at four on-farm locations in the Sacramento Valley. Nine N treatments were applied at each site with rates ranging from 0-200 lb N ac^{-1}. Urea and ammonium sulfate were both tested as N sources.
Grain yields from 2008 at the RES indicated that wet seeded conventional system reached maximum yields at N application rates of 100 lb N ac^{-1} and above, while both stale seedbed systems appeared to require 150 lb N ac^{-1} or more to achieve maximum yields. This may partially be explained by our results regarding soil N dynamics during pre-season flushes and tillage events. Soil mineral N concentrations at the RES indicate that pre-season N losses are highest in conventional systems, yet more soil N is also mineralized after the permanent flood compared to stale seedbed systems. This increase in soil N availability may reduce the need for applied N fertilizer, especially during critical growth stages occurring early in the season. Accordingly, the higher N requirements for stale seedbed systems may be related to decreased soil N mineralization and further research is required to determine the role for tillage with respect to on-farm implementation of alternative establishment practices.

Across years, the highest yields in wet seeded stale seedbed systems at the RES and on-farm sites occurred at rates of 200 lb N ac^{-1}. Yields for preflood and split N applications were similar within each system and N rate (100, 150, or 200 lb N ac^{-1}) at the RES and three out of four on-farm sites. At the RES, urea proved to be a better source of N for stale seedbed systems compared to ammonium sulfate, which on average yielded 500 lb ac^{-1} lower than other preflood 100 lb N ac^{-1} treatments. The four on-farm sites, which were all water seeded stale seedbed systems, exhibited similar trends with slightly lower N responses than the RES. Preflood N applications of 100 lb N ac^{-1} produced yields similar to higher N rates, but split rates of 25-75 lb N ac^{-1} produced significantly lower yields at three of four grower sites. Preflood and split N applications within the 150 and 200 lb N ac^{-1} treatments had equivalent yields. Ammonium sulfate treatments performed better in growers' fields; they did not produce significantly different grain yields compared to preflood 112 kg N ha^{-1} urea treatments at three of four on-farm sites.

This research contributes to our understanding of efficient N fertilizer use with respect to water management and tillage practices for improved weed control in flooded rice systems. Results from the RES and four on-farm sites suggest that minimum tillage, stale seedbed establishment systems have higher N fertility requirements than conventional water seeded systems. Alternative systems continue to respond to N rates between 150 and 200 lb N ac^{-1}, depending on seeding practices and location. Urea appears to be a more reliable N source than ammonium sulfate, and may be more attractive to growers due to a higher N analysis and ease of application. Finally, since preflood N applications generally produced similar yields to split N applications at equivalent rates across sites, these results suggest that a single N application prior to the permanent flood is sufficient to meet N fertility needs in alternative rice establishment systems.

OBJECTIVE 4. *Develop and disseminate best management practices for these systems.*

Field meetings were held in mid-August at three spring tilled stale seedbed sites and one fall tilled no spring till site. Discussion at these sites centered around the methods employed and challenges faced by the individual growers. Herbicide options and fertility management were highlighted at two of these sites and information about weed emergence modeling for these systems was discussed at one site. All these events were conducted jointly with the local UC Farm Advisors.

PUBLICATIONS OR REPORTS

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CONCISE GENERAL SUMMARY OF RELEVANT RESULTS OF THIS YEAR'S RESEARCH

Select alternative stand establishment systems tested over four years at the Rice Experiment Station (RES) at Biggs, California were tested in grower/cooperator fields around the Sacramento Valley to determine the feasibility of scaling these systems from relatively small acreage to full scale rice production. The majority of these involved the spring tilled stale seedbed technique where the field is conventionally tilled and rolled in the spring. Following this, the field is subjected to pre-plant irrigation by flushing for a period of time necessary to get sufficient germination of the weeds deemed to be the most significant deterrent to satisfactory yields. This pre-plant irrigation is aimed at encouraging germination of watergrass (incl. "mimic"), barnyardgrass, sprangletop and smallflower umbrellasedge. Late season germinating weeds, or those requiring longer and near anaerobic flooding situations for germination, were not targeted by this technique to avoid a prolonged delay in planting rice. Once a substantial flush of weed emergence has been achieved, an application of a total, non-selective, herbicide was made. The herbicide used in these cases was glyphosate, which provides control of all herbicide-resistant weed biotypes that can infest rice fields in California. Following this treatment the field is flooded and seeded without any additional tillage. Control of established weeds was complete and few grasses emerged later in the season. Follow-up herbicide combinations were tested in an imbedded trial with excellent seasonal control of weeds and good yields. Although slight to moderate yield reductions were noted in grower fields, this method is aimed at reducing the resistant late watergrass seedbank population over several years of implementation with the hope that these fields can be rotated back to more conventional systems with lower weed populations and exceptional yield. Yield reductions noted between "test" fields and other grower fields (or checks) may be due to inadequate fertility. Fertility recommendations have been based on experiments conducted at the RES. Evaluating fertility recommendations in growers fields under their management practices and soil types will be essential in the future.