COMPREHENSIVE RICE RESEARCH

ANNUAL REPORT
(January 1, 2005-December 31, 2005)

PROJECT TITLE: Weed Control in Rice

PROJECT LEADER AND PRINCIPAL INVESTIGATORS:

Project Leader:
Albert Fischer, Weed Science Program, Vegetable Crops Dept., UC Davis

Principal Investigators:
J.W. Eckert, Vegetable Crops Dept., UC Davis

Collaborating UC Scientists
J.E. Hill, Cooperative Specialist, Agronomy Dept., UC Davis
R. Tjerdeema, Environmental Toxicology Dept., UC Davis
T. Tai, USDA, Agronomy Dept., UC Davis
C. Greer, Farm Advisor, Colusa-Glenn Co.
W.M. Canevari, Farm Advisor, San Joaquin Co.
R.G. Mutters, Farm Advisor, Butte Co.

Grower Cooperators:
Thad Rodgers, Glenn Co.
Tom Inderbitzen, Yuba Co.

LEVEL OF 2005 FUNDING: $ 100,241.00

OBJECTIVES OF PROPOSED RESEARCH:

1. To test and screen herbicides for efficacy, safety and compatibility for tank mixtures or sequential treatments in order to develop, in integration with agronomic practices, weed control packages for the main rice production systems in California.

2. To continue searching and testing new compounds with potential for addressing critical weed control issues to establish their suitability and proper fit into the rice management systems of California. Encourage introduction of promising new chemicals to the California market.

3. To develop new alternatives to weed control through the exploration of agronomic opportunities, rice/weed competition to minimize herbicide costs and environmental impacts. To measure rice yield impact of specific weed species and develop a predictive approach.

4. To develop an understanding of herbicide resistance in weeds, provide diagnosis, test herbicides, and develop effective alternatives to manage this problem.

OBJECTIVE 1. *To test and screen herbicides for efficacy, safety and compatibility for tank mixtures or sequential treatments in order to develop, in integration with agronomic practices, weed control packages for the main rice production systems in California.*

Herbicide test plots were located at two different sites at the Rice Experiment Station (RES) in Butte County, one off-station site in Glenn County and one in Yuba County. One of the sites has Londax (bensulfuron-methyl)-resistant smallflower umbrellasedge. The off-station sites have resistant late watergrass as the main weed problem. The site in Glenn County was planted May 26, Yuba County was planted April 29, while planting at the Station occurred May 22 and June 3. Yield data is being presented this season for comparison between treatments, but are likely lower than what would be observed in large scale rice fields. Fertility management is lower in order to prevent lodging and poor harvest conditions with the plot combine.

All sprayed herbicide applications were made with a CO_2-pressurized (30 psi) hand-held sprayer equipped with a ten foot boom and 8002 nozzles, calibrated to apply 20 gallons of spray volume per acre. Applications with solid formulations were performed by evenly broadcasting the product over the plots.

Shark (carfentrazone)

Shark has been tested for several years on station and at off station sites in growers' fields and has demonstrated efficacy for controlling sedges and broadleaves. Because of problems in the past with non-target injury (i.e.- drift onto prunes), emphasis has been oriented towards using this product either in a DDA (direct-dry application) or DSA (direct-stream application). This season, in addition to the standard 1.2mm 40DF formulation, a 0.6mm extruded 40DF formulation and a 2% clay granule were tested. All three formulations were tested as direct-dry applications. The dry application into the water allows reduced potential for non-target drift, and to cover large acreages effectively for early weed control. The new formulations are being tested to determine the most efficacious formulation for dispersion of chemical and therefore control of target weeds. Shark is particularly important to California rice since resistance to Londax (bensulfuron) is widespread. Shark is an effective tool in California rice as it can be applied in combination with other into-water herbicides, and in sequential weed control operations.

Identical trials were set up, one early seeding (April 29, 2005) at a cooperators field and a late seeding (June 23, 2005) at the Rice Experiment Station (Tables 11 & 21). Each trial had Shark application timings of pre-flood surface, prior to weed emergence, 1-2 leaf stage rice, 3-4 leaf stage rice and 1-2 tiller rice. The bulrush population was much greater at the late seeded site than the early site. The lower bulrush population at the early site is partly due to excessive early competition by resistant late watergrass. This watergrass could not

be controlled by Clincher (cyhalofop) herbicide. Ricefield bulrush control was strongly related to its size at the time of application.
Best control was obtained when bulrush was just beginning to emerge from the soil surface. At that point the plant would absorb the chemical directly through the emerged (from Shark dissolved in water) or emerging (from Shark in the soil solution) tissues and perhaps even by root uptake. Thus, seedlings get killed as they emerge and receive light. Germination must have been rather synchronous, since by 60 DAS the control for both seeding dates was still high, suggesting few late emerging cohorts. Weed control at 40 DAS represents the herbicide's efficacy to remove weeds during the critical period of competition. Consequently, under the cooler temperatures associated with the early seeding, the best application timing was when rice was at the 1-2 leaf stage, but for the late seeded site this timing was too late because bulrush had by then grown up to 0.75" tall and control was only about 50%, under these warmer conditions. At this timing (1-2 lsr) rice may have marginal tolerance to this herbicide. Applications of Shark to rice at the 2 leaf stage or less requires that the rice be well pegged in the soil. When bulrush was 2" tall control at either site was equally poor, of about 50%. Thus, bulrush size at application was key for herbicide effectiveness.
Therefore, Shark should be used as early as possible with bulrush plants well below 1" tall. For safety rice should have no less than 2 leaves and be well pegged. This favorable growth difference between rice and bulrush for achieving safety and maximum control is more likely to occur when rice is seeded early than when seeded late. Warmer temperatures in late seeded rice promote vigorous bulrush growth and emergence rates at a time when rice is still small, thus compromising the safety and control.
The effect of cold water on Shark effectiveness when rice is seeded very early still needs to be addressed.
The early planting was not harvested for yield due to the excessive resistant watergrass that caused lodging of the crop at that site.

Shark applied at the same time as Granite GR provided excellent broad-spectrum control and the second highest yield at the RES continuously flooded trial (Table 4). Shark would control ALS-resistant weeds that could escape Granite and would improve smallflower control. At a resistant watergrass site Shark applied at 2-3 leaf stage rice following a day of seeding (DOS) application of Cerano, provided good broad-spectrum control and the second highest yield for the continuously flooded trial (Table 22).

Prowl H_2O (pendimethalin)

Prowl is a selective herbicide for controlling annual grass (watergrass, barnyardgrass, sprangletop) and certain broadleaf weeds as they germinate and emerge. As a meristematic inhibitor, it interferes with the plant's cellular division and early growth. Prowl H_2O has substituted Prowl EC on the supplemental label for drilled and dry seeded rice in California. Prowl H_2O is a new water based capsule suspension (CS) formulation. Wet/dry cycles cause the capsule wall to rupture and release the pendimethalin. Prowl H_2O needs to be applied to moist soil without any standing water. Flooding causes the chemical to degrade and loose efficacy; also volatility losses are more rapid when this herbicide is applied to wet soil surfaces. Prowl H_2O was tested in a pinpoint method both at a resistant watergrass site and at the RES. Prowl H_2O was also tested at the RES in a Leather's method trial and a drill seeded trial.

At the resistant site, the best broad-spectrum control and best yield for the pinpoint study was when Prowl H_2O was tank mixed with SuperWham (5-6 lsr) following an application of Cerano (DOS) (Table 3). The second best yield was with a tank mix of Prowl H_2O, Abolish and Regiment (4-5 lsr). A third tank mix with good results was Prowl H_2O plus SuperWham (5-6 lsr). None of these treatments were statistically significant. Prowl is intended to help when reflooding fields is slow allowing watergrass, sprangletop and barnyardgrass plants to emerge. This was not the case in this study due to the inability to keep water off the trial for the length of time to see this impact. Efficacy of these mixtures are probably mainly due to the tank mix partners of Prowl.

Prowl H_2O was tested in a pinpoint system at the RES site (Table 6). Prowl applied alone provided 58% control of watergrass and 36% control of sprangletop while improving yield over the untreated control. The best overall efficacy and yield were obtained with a tank mix of Prowl H_2O plus Regiment (3-5 lsr) followed by a Clincher application (1-3 till). Other good combinations are Prowl H_2O tank mixed with Clincher (3-5 lsr) followed by SuperWham (1-3 till) and Prowl H_2O tank mixed with SuperWham (3-5 lsr) followed by Clincher (1-3 till).

Prowl H_2O was tested for efficacy in a Leather's method trial at the RES (Table 7). Prowl H_2O (1-2 lsr) applied alone provided 66% control of watergrass and 28% control of sprangletop. One of the best overall weed control treatments and best yield was achieved with a tank mix of Prowl H_2O and Clincher (1-2 lsr) followed by a SuperWham application (1-3 till). A tank mix of Prowl H_2O and Clincher (1-2 lsr) followed by Regiment (1-3 till) provided less sedge control and lower yield.

Prowl H_2O was also tested in a drill seeded rice culture at the RES (Table 12). Prowl H_2O applied alone (delayed pre-emergent) provided 72% watergrass control and 92% sprangletop control. Improved control of grasses was achieved with Clincher in tank mix with Prowl H_2O (early post emergent) and improved grass and sedge control was achieved with a tank mix of Prowl H_2O and SuperWham (early post emergent). SuperWham and Clincher in these tank mixes provide control of established grass while the Prowl prevents establishment of germinating grasses. Prowl generally works better in dry/drill seeded aerobic conditions than in water seeded systems. In water seeded conditions Prowl works better when conditions require delayed or slow re-flood.

IR-5878 WG

IR-5878 is an ALS inhibitor that was tested for an eighth season at the RES for broad-spectrum activity at a site with susceptible watergrass and Londax-resistant smallflower umbrellasedge. The field preparation where the IR-5878 trials were run this season was delayed several times by rain events. It is speculated that this contributed to a fast germination of weeds at the time of flood up for establishment. The precocious weed establishment at this site made control more challenging for all herbicides tested.

IR-5878 WG was tested in a standard pinpoint trial, a pinpoint application following a basin application of Cerano and in a Leather's method trial. The two pinpoint studies had IR-5878 applications at the 3-4 lsr timing (Tables 13 & 15). The control of watergrass was poor in both studies while control was good in 2004 when applied at 2-3 lsr. This suggests that IR-5878 needs to be applied very early for good efficacy on watergrass. Excellent bulrush control was achieved with IR-5878, but control of resistant smallflower umbrellasedge was marginal. There may be tank mix antagonism between IR-5878 and Clincher. Clincher normally controls sprangletop completely. When it is tank mixed with IR-5878 control of sprangletop is reduced to 70%, but when Clincher is applied separately on the same day after IR-5878, control is 98%. Watergrass control in this treatment is lower than would be expected with Clincher suggesting antagonism even when the two compounds are applied separately. Applying Clincher a few days prior to application of IR-5878 would likely eliminate any chance of antagonistic response. A similar effect may be happening with SuperWham. SuperWham normally controls 80% of watergrass when applied at this stage, but when in tank mix with IR-5878 the control is only 48%. Therefore, separate applications would be indicated in this situation also.

IR-5878 improves control of watergrass after a treatment of Cerano. Excellent control of bulrush and partial control of smallflower umbrellasedge is achieved after the initial application of Cerano, which does not control these weeds. Adding SuperWham as a tank mix partner of IR-5878 improves the control of broadleaf and sedge weeds and resulted in the highest yield of the study. Here again, watergrass control was not as high as would be expected from the Super Wham treatment, suggesting a tank mix problem.

IR-5878 did not perform well in the Leather's method experiment most likely due to the timing of the application at the 3-4 lsr (Table 14). The delay in application with this method resulted in a later application than even the pinpoint trials. Watergrass was already at the 1-2 tiller stage, resulting in poor control and low yields. Bulrush control was excellent but this did not translate to any yield advantage.

IR-5878 GR

This is the third season of experimentation with this granular formulation of IR-5878. This herbicide is being tested in a continuous flood system and applications were made into 16x25-ft flooded levee plots (Tables 16 & 17). The best overall weed control and yield was achieved with a treatment of Cerano and IR-5878 applied at 0.5 lsr followed by Clincher (1-3 Till). IR-5878 GR adds watergrass, bulrush and ducksalad control beyond that of Cerano applied alone. Lowering the rate of IR-5878 from 149 to 84 g ai/ha tends to lower the control of bulrush and ducksalad. The best yielding treatment in the program study (Cerano and IR-5878 GR applied at 0.5 lsr with a follow-up of SuperWham at 2-3 Till) was not the best weed control treatment. The best weed control treatment was IR-5878 (0.5 lsr) followed by Granite GR (2-3 lsr) followed by SuperWham (2-3 Till). This treatment had the second best yield in the study, but not statistically different from the highest yielding treatment. In the trial looking at phytotoxicity there appears to be no apparent impact on rice by IR-5878. One of the best overall weed control treatments was Cerano (0.5 lsr) followed by IR-5878 (1-2 lsr) followed by Clincher (1-3 Till). It was also the best yielding treatment.

Granite GR (penoxsulam) alone and in combinations

Granite GR is an ALS inhibiting post-flood, post-emergence herbicide for selective control of susceptible grass (not active on sprangletop), broadleaf and sedge weeds in California rice. The granular formulation, Granite GR was first available commercially during the 2005 season. This product was applied into the water at 40 g ai/ha 8-9 days after seeding. It was tested alone and in combination with Bolero, Cerano, propanil, Clincher and Shark (Table 9). Most treatments provided good to excellent weed control. Plants at the 3 leaf stage exhibited noticeable root stunting. This effect was short lived and the plants recovered. The best yielding Granite combination was Granite GR (2-3 lsr) followed by Clincher (1-2 Till) followed by Stam (3 Till). Other good treatments were: Bolero (2-3 lsr) followed by Granite GR (2-3 lsr) followed by Stam (3 Till) and Granite GR (2-3 lsr) followed by Stam (5 lsr) followed by Grandstand (3 Till). A separate experiment tested the plant response and yield to label rates and double label rates of Granite GR compared to Cerano, Bolero, and Ordram (Table 10). Injury to the crop was not seen with Granite GR, Bolero or Ordram, while injury was significant with Cerano especially with the double rate. Early root stunting and plant stunting was noted with Granite GR, however doubling rate did not impact yield and yields with Granite 2X were comparable to those of the safest treatment. The Cerano treatments had lower yield than the rest of the treatments. This could be due to the notorious injury (bleaching) observed with Cerano 2X. Granite GR had slightly higher yields than either Bolero or Ordram, although not statistically significant.

Granite SC (penoxsulam) alone and in combinations

Granite SC is a liquid formulation of penoxsulam for foliar application. It is likely to be labeled for California beginning in 2006. It was tested in a pinpoint flood system with flood water dropped for an application at the 3-4 lsr (Table 8). It was applied at two rates (35 & 70g ai/ha) with a separate application of Clincher (3-4 lsr). It was compared to Regiment with separate application of Clincher (all at 3-4 lsr). Granite SC provided excellent broad-spectrum weed control and the highest yields for the study. The 70g rate provided slightly better weed control and yield than the 35g rate, however this may not be cost effective. The root stunting seen with the granular formulation was not noticeable with this formulation.

GWN-3040 (halosulfuron methyl)

Halsulfuron methyl is an ALS inhibitor that has been available for California rice production under the Monsanto trade name Sempra. Gowan chemical will be taking over marketing halsulfuron methyl in California under the trade name Sandia. Halsulfuron methyl is an ALS inhibitor that is used to control broadleaf and sedge weeds in rice. Halsulfuron can be applied directly to flooded rice or applied as a foliar spray in a pinpoint flood system. When applied in a pinpoint flood system the tank mix with Regiment (1-2 Till) provided the best overall weed control and the best grain yield (Table 19). This mixture is not advisable given that both herbicides have the same mode of action and resistance to ALS inhibitors is widespread in California among sedges and broadleaf weeds. Repeated use of this mixture might even select for ALS resistance in grasses. It also performed well in tank mix with propanil or by itself. Later applications (1-2 Till) did not perform well and had lower yield.

When applied alone in continuously flooded rice, halsulfuron methyl (1-3 lsr) provides good watergrass control and excellent sedge control (Table 20). Better broad-spectrum control and higher yields were achieved when halsulfuron was either tank mixed with Abolish (1-3 lsr) or followed an application of Cerano (0.5 lsr).

WH-105

WH-105 is being tested alone and in combination with Cerano, Abolish, Bolero, Shark, and SuperWham (Table 18). Bulrush and watergrass were problematic in this field due to poor conditions for establishment (multiple rain events during field setup) leading to early growth of grasses and bulrush. Control by most herbicides was mediocre at this site. When applied alone (DOS-0.5 lsr), control of susceptible watergrass was excellent while control of bulrush and ducksalad was poor. The best yielding treatment was a pre-flood application of Abolish followed by an application of Cerano (0.5 lsr) then followed by a treatment of WH-105 (0.5 lsr). Watergrass was completely controlled while bulrush control was 64% and Ducksalad control was 13%. The second best treatment was the same except the Cerano was applied at half the standard rate. Other treatments that were effective for control of watergrass and bulrush were WH-105 (DOS-0.5 lsr) followed by SuperWham (1-3 Till) and WH-105 and Cerano applied at 0.5 leaf stage. Both of these treatments provided excellent watergrass control and good bulrush control. WH-105 was also tested with several other herbicides in combination granules. These granules need further study to determine their efficacy. The advantage of combination granules is the reduction of herbicide applications and reduction of potential drift.

OBJECTIVE 2. *To continue searching and testing new compounds with potential for addressing critical weed control issues to establish their suitability and proper fit into the rice management systems of California. Encourage introduction of promising new chemicals to the California market*.

In recognizing the need for developing herbicides to meet the cultural needs of growers throughout the state, our herbicide testing system was designed around the various types of irrigation schemes that growers use. These include: Continuous flood, pin-point flood, Leather’s method and dry/drill seeding with flush irrigation.

Continuous flood system combinations

Continuous flood trials were conducted at the Hamilton Road site at the Rice Experiment Station and at two resistant sites on cooperator grower’s land. The Hamilton Road site has susceptible weed species while the two off station sites have resistant late watergrass. In most cases the applications were sequential comprising an initial application of Cerano, Granite GR, Bolero or Ordram for watergrass control followed by an application of Shark, Londax, Super Wham, or Regiment at various timings (Table 4) to control broadleaves, sedges, and in some cases late-emerging watergrass plants or those missed by the early treatment. Granite GR is a newly available granular herbicide that was tested alongside other standard herbicides used by growers. At the RES, one of the best treatments for weed control was Granite GR (2-3 lsr) followed by Stam (1 Till) (Table 4). This treatment also had the highest yield in this trial. Other good treatments for weed control and descending yield were: Shark (2-3 lsr) followed by Granite GR (2-3 lsr), Cerano (DOS) followed by Granite GR (2-3 lsr), Bolero (1-2 lsr) followed by Shark (2-3 lsr) followed by SuperWham (1-3 Till), and Abolish (PFS) followed by Granite GR (2-3 lsr).

At the Glenn County resistant late watergrass site there was no treatment that controlled the grass completely. The best treatment for weed control was Granite GR (2-3 lsr) followed by SuperWham (1-3 Till) (Table 1). Other good treatments were; Bolero (1-2 lsr) followed by SuperWham (1-3 Till) and Wham 60 DF (1-3 Till) alone. These two treatments provided less control of watergrass and smallflower umbrellasedge than the Granite GR followed by SuperWham. Granite GR tends to stunt the growth of rice by hindering root growth during the period that the chemical is active.

At the Yuba County resistant late watergrass site, control of watergrass was critical for yield of rice. The watergrass at this site is a very early and fast growing selection. The best watergrass control and highest yield was attained with a treatment of Granite GR (2-3 lsr) followed by a tank mix of SuperWham and a low rate of Whip (intended for sprangletop control) (1 Till) (Table 22). The second best treatment was Cerano (DOS) followed by Shark (2-3 lsr). This treatment was also highy efficacious on watergrass. The watergrass at this site appears to be resistant to Abolish and Bolero but was suppressed by Cerano and Granite.

Pin-point flood system combinations

Pin-point flood trials were conducted at the susceptible watergrass site at the RES and at resistant watergrass sites in Glenn County and Yuba County. All trials were drained several days prior to initial application and then re-flooded several days after application. Follow up applications of foliar herbicides requires lowering of water to achieve 70% weed exposure for effective treatment.

Main weeds were late watergrass, ricefield bulrush, smallflower umbrellasedge, sprangletop, and ducksalad. Many of the treatments tested at the susceptible RES site had similar yields (Table 5). The following treatment combinations gave good weed control: tank mix of Clincher, Stam and Granite SC (3-4 lsr); Clincher (3-4 lsr) followed by Granite SC (1-2 Till); Regiment (3-4 lsr) followed by SuperWham (1-2 Till); tank mix of SuperWham and 2,4-D (1-2 Till); Stam (1-2 Till); Wham (1-2 Till).

The best overall treatments at the Glenn County resistant site were: Regiment tank mixed with Abolish (3-4 lsr) followed by SuperWham (1 Till), SuperWham (3-4 lsr) followed by Regiment (1 Till), Clincher (3-4 lsr) followed by SuperWham (1 Till), Regiment (3-4 lsr) applied alone and SuperWham (3-4 lsr) followed by Clincher (1 Till) (Table 2). It appears that early (3-4lsr) applications of SuperWham are missing bulrush probably due to later flushes of this weed.

The best treatment at the Yuba County resistant site was a high rate of Regiment (4-5lsr) followed by a tank mix of SuperWham plus Whip (1-3 Till), although the yield was very low (Table 23). Future testing of the pinpoint method at this site should shift treatment timing to the 3-4 lsr in order enhance suppression of the vigorous watergrass.

Leather's method system

The Leather's method is a system where water seeding is followed by draining most of the initial flood water to encourage faster rice establishment. Final flood water is applied when the rice can sustain the flood. This method leaves the soil surface aerobic for an extended period of time, which allows certain weed species to flourish, especially sprangletop. Foliar herbicides are applied during this exposed period prior to final flood. Prowl H_2O and Granite SC are two new herbicides that were tested in this system. Prowl H_2O is a soil active compound that is effective on germinating weeds but not on established weeds. Granite SC is a foliar active herbicide that is effective on most rice weeds except sprangletop.

The best overall weed control and yield was achieved with a tank mix of Prowl H_2O and Clincher (1-2 lsr) followed by SuperWham (1-3 Till) (Table 7). Clincher provides the initial control of watergrass and sprangletop and Prowl provides the extended control of germinating grasses. SuperWham provides additional late season control of grasses, sedges and broadleaves. Granite SC (1-2 lsr) applied alone provided the second best yield and good control of watergrass, bulrush, smallflower umbrellasedge and ducksalad but poor control of spangletop. Other good treatments include: tank mix of Abolish and SuperWham (1-2 lsr), controlling watergrass, smallflower umbrellasedge and sprangletop and to a lesser extent bulrush and ducksalad; a tank mix of Granite SC and Clincher (1-2 lsr) had lowered control of most weed species as compared to Granite SC alone. The only exception is sprangletop, which was completely controlled by Clincher.

Drill seeded system

Rice seed was drilled into dry ground, then flush-irrigated for establishment. Additional flush irrigations were applied to insure good establishment. Standing water inhibits establishment of the rice that is drilled into the soil. The main weeds in this system were watergrass, ricefield bulrush and sprangletop. Herbicide timing included delayed pre-emergent (DPRE) after the first flush of irrigation, early post emergent (EPE) with rice at the 2-3 lsr, late post-emergent (4-6 lsr), and post permanent flood (PPF) with rice at the 1-2 tiller stage. The best yielding treatment and best broad-spectrum weed control was achieved with a tank mix of Abolish and Regiment (4-5 lsr), a synergistic mixture on watergrass, followed by Clincher (PPF) (Table 12). Lower rates of Abolish and Regiment maintained high watergrass control, but control of sedges was poor. The second best yielding treatment was Abolish (DPRE) followed by Clincher (5-6 lsr). This treatment controlled a broad-spectrum of weeds except bulrush. Other good broad-spectrum treatments were: tank mix of Abolish and SuperWham (EPE), Shark (5-6 lsr) followed by Clincher (PPF), Clincher (5-6 lsr) followed by SuperWham (PPF), and SuperWham (5-6 lsr) followed by Clincher (PPF). Control of sprangletop is essential to respectable yields in a drill seeded crop; Abolish and Clincher control this weed. Shark (5-6 lsr) followed by either SuperWham or Regiment (PPF) did not control sprangletop and, therefore, had the lowest yields of the experiment.

OBJECTIVE 3. *To develop new alternatives to weed control through the exploration of agronomic opportunities, rice/weed competition to minimize herbicide costs and environmental impacts. To measure rice yield impact of specific weed species and develop a predictive approach.*

HERBICIDE RESISTANCE WEED MANAGEMENT SYSTEMS IN RICE USING ALTERNATIVE STAND ESTABLISHMENT TECHNIQUES

Rationale: Integrating cultural and chemical weed control practices may increase cost efficiency of weed management through the reduction of herbicide resistant weed populations, delayed evolution of herbicide resistance, and timely reduction of weed seed banks. Alternative cultural rice establishment techniques such as drill seeding, stale seedbed, or no-till may be used to manipulate weed species recruitment and expand herbicide options. In drill-seeded rice, pendimethalin (Prowl) may be used for soil residual control of many grass species. In stale seedbed systems, weeds that emerge prior to rice planting may be controlled with non-selective herbicides such as glyphosate (Roundup). These herbicides provide alternative mechanisms of action, may be less expensive, and may be more environmentally benign than some of the herbicides used in conventional water-seeded rice systems. Therefore, a large field experiment was established at the Rice Experiment Station to quantify weed species recruitment and the efficacy of herbicides unique to specific rice establishment systems.

Establishment procedures for each treatment:

1. *Water-seeded, conventional*: Plots were established using conventional California water-seeding procedures that included spring tillage, flooding to a depth of approximately 4 in, and aerial rice seeding within two days of the permanent flood (Table 24). In 2004, plots were planted immediately after levees were completed, but in 2005 planting was delayed to coincide with the stale seedbed treatments. Rice seed (M202) was planted at a rate of 150 lbs per acre.

2. *Drill-seeded, conventional*: Plots were spring tilled and rice seed was planted approximately 0.5 in deep using a 10 ft wide grain drill. Rice seed (M202) was planted at a rate of 100 lbs per acre. The permanent flood was applied approximately 30 d after planting in each year.

3. *Water-seeded, spring tillage, stale seedbed*: Plots were spring tilled and then flushed with water to induce weed emergence prior to a pre-plant application of glyphosate 2 d before application of the permanent flood and aerial rice seeding. In 2004, flushing included flooding the plots for 1 d before draining, but in 2005 plots remained flooded for 6 d to increase recruitment of aquatic weeds. Heavy rain in 2005 re-saturated the soil approximately 5 d after flushing but prior to application of the permanent flood. Rice seed (M202) was planted at a rate of approximately 150 lbs per acre.

4. *Water-seeded, no tillage, stale seedbed*: Plots were not tilled in the spring or fall in either year. The stale seedbed procedures included flushing in early to mid-May in each year followed by an application of glyphosate 2 d before establishing the permanent flood and aerial rice seeding. Rice seed (M202) was planted at a rate of approximately 150 lbs per acre.

5. *Drill-seeded, no tillage, stale seedbed*: Plots were not tilled in the spring or fall in either year. Plots were flushed in early to mid-May in each year prior to drill seeding. After flushing, at least 8 d was required in each year for the soil to adequately dry to permit planting with the tractor and grain drill. Rice seed (M202) was planted using similar procedures as treatment 2.

Weed recruitment among systems: Rice establishment systems greatly affected weed species recruitment and weed densities in each year. Drill-seeded rice treatments were dominated by grasses whereas water-seeded treatment were dominated by sedge and broadleaf weed species in each year (Table 25). Among water-seeded plots in 2005, smallflower umbrellasedge densities decreased by approximately 50% from the conventional to spring-tilled stale seedbed treatment, but decreased by approximately 90% from the spring-tilled stale seedbed to the no-till stale seedbed treatment. Between the drill-seeded plots, *Echinochloa* densities declined by approximately 85% but sprangletop densities increased 5-fold from the conventional to the no-till stale seedbed treatment. In 2004, one conventional drill-seeded plot contained 160 *Echinochloa* weeds per m^2, which caused 85% rice yield loss in the weedy check area. Across replications, rice yield loss in the weedy checks averaged 14% in the conventional water-seeded plots, 37% in the conventional drill-seeded plots, but less than 5% in each of the stale seedbed plots in 2004.

Since the weedy checks were located in the same area in each year, populations of weed species often increased from 2004 to 2005. Thus, weed populations in Table 2 represent post-emergence weed recruitment associated with each tillage system and potential increases in weed populations between years. In each water-seeded treatment, smallflower umbrellasedge populations increased by approximately 7-fold from 2004 to 2005 and redstem densities increased to 70 plants m^{-2} regardless of the density the previous year. In the drill-seeded treatments, grass weed species increased approximately 2-fold in the conventional and over 10-fold in no-till stale seedbed treatments from 2004 to 2005.

Herbicide applications and weed control: Adequate weed control was achieved with the selected herbicides for each treatment. In the water-seeded treatments 1 and 3, sedge weed species were controlled (> 90%) with a late-season (3-4 rice tiller) application of propanil (6 lbs./a.i./acre) in 2004 and a tank-mixed application in 2005 of propanil/bensulfuron (6 lbs/a.i./acre, 0.6 oz/a.i./acre, respectively) for added control of greater redstem populations in all water-seeded treatments. No post-emergence herbicide was needed in the water-seeded, no-till, stale seedbed treatment in 2004 as weeds were not present. In the drill-seeded treatments, a tank-mixed application of pendimethalin/cyhalofop-butyl (1 lb./a.i./acre, 0.24 lbs./a.i./acre, respectively) resulted in > 85% control of these grass species. A late-post emergence application of propanil (6 lbs/a.i./acre) was needed for *Echinochloa* escapes in each drill-seeded plot in 2005. Glyphosate (1.2 lbs./a.e./acre) was applied approximately 2 d prior to the application of the permanent flood in each year. Glyphosate used in the stale seedbed systems greatly reduced post rice emergence weed densities in the water and drill-seeded systems.

As in 2004, there were no statistical differences in yield among the different systems. Yields In kg/ha at 14% moisture in 2005 were: *Water-seeded, conventional* 8170, *Drill-seeded, conventional* 8410, *Water-seeded, spring tillage, stale seedbed* 7382, *Water-seeded, no tillage, stale seedbed* 8175, *Drill-seeded, no tillage, stale seedbed* 8292.

<u>Conclusions</u>:

These results suggest that integration of cultural and chemical weed control practices provide additional options for weed management in continuous rice. Drill seeding rice followed by an early post-emergence application of pendimethalin may effectively reduce seed banks of grass species biotypes that are resistant of conventional water-seeded rice herbicides. Adding a stale seedbed component to this system will reduce post-emergence weed pressure in highly infested fields. In water-seeded/stale seedbed systems, eliminating spring tillage greatly reduced populations of sedge weed species. Modeling approaches are being evaluated to identify optimal rotations of these establishment systems for managing problematic weed species and herbicide resistant biotypes.

OBJECTIVE 4. *To develop an understanding of herbicide resistance in weeds, provide diagnosis, test herbicides, and develop effective alternatives to manage this problem.*

Diagnostic and detection of herbicide resistance

A study is being conducted to elucidate the basis for the current distribution of herbicide-resistant *Echinochloa* spp (early and late watergrass, and barnyardgrass) in California rice. Two-hundred and forty seed samples were collected in the fall of 2003 from throughout the rice growing region of the Sacramento Valley. Some grower-submitted samples were included in this group. All seed samples were tested for resistance to Bolero, Ordram, Regiment, Clincher. Because it is known that herbicides tend to be over active in greenhouse conditions, all materials were applied at ½ the standard rate and the standard rate. Bolero was applied at 2240 and 4480 g ai/ha at the 1-2 leaf stage of grass (lsg). Ordram was applied at 2240 and 4480 g ai/ha at the 1-2 lsg. Regiment was applied at 20 and 40 g ai/ha at the 1-3 tiller stage. Clincher was applied at the rates of 63 and 126 g ai/a at the 1-3 tiller stage. Susceptible and resistant controls are included in the test. The resistance testing was used to select samples that are susceptible, partially resistant and highly resistant. These samples will have further testing and genetic analysis to determine their relatedness. This will allow

Mechanisms and distribution of herbicide resistance in weeds of rice.

We continued our work to characterize different mutations conferring resistance to ALS inhibitors in smallflower umbrellasedge. This is important to clarify the scope of usefulness of the different ALS inhibitors available and those seeking registration. We also continue our research on the dispersion of resistant smallflower biotypes. Clarification of the mechanism of resistance to thiocarbamates (Abolish, Bolero, ordram) is in progress. This is important, since repeated use of these herbicides drove the evolution of herbicide resistance in Echinochloa spp. In California; knowledge of the mechanism allows the design of herbicide use strategies for resistance management. We have elucidated, in collaboration with Dr. R. Tjerdeema's lab, the role of herbicide metabolism in Cerano (clomazone) toxicity to watergrass. This herbicide needs to be degraded to an active metabolite for toxicity and control. This process is inactivated by organophosphate insecticides that normally synergize other herbicides (and result in toxicity to rice). Use of this type of insecticide close to a Cerano treatment will lower its effectiveness on watergrass control (and may lower herbicide toxicity on rice as well). The mechanism of watergrass resistance to Granite (penoxsulam) is being investigated in greenhouse experiments. It is likely that this resistance is mediated by an enhanced degradation ability similar to that observed with resistance to other herbicides.

PUBLICATIONS OR REPORTS

1. Ruiz-Santaella, J.P., Y. Bakkali, A.J. Fischer, and R. De Prado. 2003. Is it possible to detect *Echinochloa* spp. tolerance to ACCase-inhibiting herbicides using a simple quick tolerance test? Comm. Appl. Boil. Sci., Ghent University, 68(4a):331-334

2. Ruiz-Santaella, J.P., A.J. Fischer, and R. De Prado. 2003. Alternative control of two biotypes of *Echinochloa phyllopogon* susceptible and resistant to fenoxaprop-ethyl. Comm. Appl. Boil. Sci., Ghent University, 68(4a):403-407.

3. Merotto, Jr., A. and A.J. Fischer. 2004. [Absorption and translocation of herbicides in plants] Absorção e traslocação de herbicidas nas plantas. Pages 89-104 *In* L. Vargas and E. Scherer Roman (eds.) [Handbook for the Management and Control of Weeds] Manual de Manejo e Controle de Plantas Daninhas. EMBRAPA Uva e Vinho, Bento Gonçalves, RS, Brazil.

4. Machida, T., Y. Yamasue, A. J. Fischer, and J. E. Hill. 2005. Growth and seed production of multiple-herbicide resistant biotypes of late watergarss in California. Abstracts Weed Science Society of America Conference. Hawaii. 45.

5. Moechnig, M., A.J. Fischer, J.W. Eckert. 2005. Utilizing drought stress to control ricefield bulrush (*Schoenoplectus mucronatus*) in organic rice fields. Abstracts Weed Science Society of America Conference. Hawaii. 45.

6. Merotto, A., M. D. Osuna, A. J. Fischer, and M. Jasieniuk 2005. Distribution of cross-resistance patterns to ALS-inhibiting herbicides in *Cyperus difformis* L. in California rice. Abstracts Weed Science Society of America Conference. Hawaii 45.

7. Osuna, M.D., I. Abdallah, A. J. Fischer, W. T. Jewell [1] and M. A. Zaki. 2005. Thiobencarb metabolism in two *Echinlochloa phyllopogon* biotypes in California. Abstracts Weed Science Society of America Conference. Hawaii. 45.

8. Pérez de Vida, F.B., A. J Fischer, D. Mackill, E. Laca, and G. M. Fernández. 2005. Rice traits related to yielding ability under watergrass (*Echinochloa phyllopogon*) competition. Abstracts Weed Science Society of America Conference. Hawaii. 45.

9. Yun, M.S., Y. Yogo, R. Miura, Y. Yamasue, and A.J. Fischer. 2005. Cytochrome P-450 monooxygenase activity in herbicide-resistant and –susceptible late watergrass (*Echinochloa phyllopogon*). Pestic. Biochem. Physiol. 83:107-114.

10. Abdallah, I., A.J. Fischer, C.L Elmore, M. E.Saltveit, and M. Zaki. 2006. Mechanism of Resistance to Quinclorac in Smooth Crabgrass (*Digitaria ischaemum*). Pesticide Biochemistry and Physiology 84:38-48.

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

This year we continued to develop herbicide programs for water-seeded and drill seeded rice. Herbicide efficacy, including new compounds, tank-mix combinations and sequential applications continues to be a major emphasis of the program. We also tested new compounds, including one broad-spectrum herbicide that was available this season. Testing continues on several herbicides that have potential for the California market. This work was conducted at the Rice Experiment Station and on a cooperating grower's property in Glenn and Yuba Counties where highly resistant late watergrass exists. In addition, the program includes experiments that evaluate alternative crop establishment methods as a means of altering weed dynamics and diversifying herbicide options to manage herbicide-resistant weeds in rice. Research also addresses non-chemical options for weed management. Funding for our research program from the California Rice Research Board is expanded with additional funding from other grants.

Herbicide efficacy of currently registered and potential new herbicides has become a more crucial issue in recent years with the development of herbicide resistant weeds. Cerano, (clomazone) a pigment synthesis inhibitor,that has repeatedly demonstrated high efficacy to control barnyardgrass, watergrass (*Echinochloa* spp.) and sprangletop (*Leptochloa* *fascicularis*), but has been less effective against herbicide-resistant watergrass. Very good broad-spectrum weed control was obtained with Cerano used in combination with SuperWham (propanil), Regiment (bispyribac-sodium) or Granite GR (penoxsulam). At the resistant site Granite GR followed by SuperWham provided good watergrass control. Shark (carfentrazone) into-the-water was tested at early (April 29) and late (June 3) planting times to determine efficacy against ricefield bulrush. Timing of Shark is dependent on the growth of bulrush at these different planting dates. Early season planting is during cooler weather where bulrush is slow to establish, but bulrush established faster under warmer weather conditions following the later seeding time. Bulrush control diminished drastically as plants grew larger and only 50% control was obtained by the time bulrush reached two inches tall. Therefore, Shark should be used as early as possible with bulrush plants well below 1” tall. For safety rice should have no less than 2 leaves and be well pegged. IR-5878 is a granular sulfamoylurea (ALS inhibitor) that worked well in continuously flooded systems in broad-spectrum programs involving Cerano, Super Wham or Clincher. The foliar formulation of IR-5878 did not perform as well in the pinpoint flood trial as the granular did in the continuously flooded trial.Granite GR (penoxsulam) is an ALS inhibiting post-flood herbicide for selective broad-spectrum control (not active on sprangletop and weak on resistant late watergrass). This formulation was available for use in 2005 and the SC foliar formulation will likely be available in 2006. The granular formulation worked well in continuously flooded rice. Plant and root stunting was noted during the period when the chemical is active in the water, but this effect diminishes over time. It performed well on susceptible weeds as a sequential following Cerano and Abolish, or followed by SuperWham (propanil) or Clincher. As with all ALS-inhibiting compounds, Granite will likely fail to control certain biotypes that are resistant to the mode of action of this compound. Regiment is a post emergent herbicide applied with a silicone surfactant. It is effective on watergrass, ricefield bulrush, and demonstrates good activity on California arrowhead. Regiment was tested alone, in tank mixes, and in sequences. A tank mix of Regiment and Abolish provided 79% control of resistant watergrass and 65% smallflower control.

Pinpoint flood systems generally involve one or more foliar active herbicides in tank mix or sequential applications. Regiment performed well in pin-point systems in sequence with Clincher (cyhalofop-butyl) and SuperWham. Tank mixes of Regiment and either Clincher or SuperWham were antagonistic. Clincher (cyhalofop-butyl) is a post-emergent ACCase inhibitor that controls watergrass and sprangletop and is very safe on rice. Clincher appears to work best when applied as a sequential in pin-point systems. Very good broad-spectrum control was obtained when Clincher followed SuperWham at susceptible and resistant watergrass sites. Prowl (pendimethalin) is a meristematic inhibitor that interferes with the plant’s cellular division and early growth. The new H_2O (CS) formulation will replace the EC formulation on the dry/drill-seeded rice label in California, while the potential of this formulation will continue to be tested for water-seeded rice. This herbicide is active in aerobic moist soil but appears to be rapidly inactivated in flooded rice. Prowl H_2O could be used in water seeded pin-point rice where ability to rapidly reflood after foliar herbicide treatments is diminished by limited water supply or large checks.

The Leathers' method is a water-seeded system where the flood water is dropped after seeding in order to allow improved establishment of rice. This period of extended soil exposure also encourages certain weed species to establish. Prowl H_2O in tank mix with either SuperWham or Clincher provided excellent grass (barnyardgrass, watergrass and sprangletop) control. Prowl H_2O with a follow-up treatment of SuperWham also was an excellent treatment. Other good treatments (including sprangletop control) included: Abolish in tank mix or sequence with SuperWham, Clincher in sequence with SuperWham, Regiment or Granite SC.

Drill seeded rice is a system that allows use of different herbicides than water seeded rice, but also allows different weed species to flourish. Watergrass, barnyardgrass and sprangletop are three common weedy grasses found in this system. Good control can be achieved with Prowl H_2O alone or in combination with Clincher, SuperWham, or Regiment. Abolish in combinations with SuperWham, Regiment or Clincher were also very good treatments, as was also Clincher followed by SuperWham.

Research continued on alternative rice establishment systems for their potential to shift and reduce weed species recruitment and facilitate the use of alternative herbicides such as pendimethalin and glyphosate that have mechanisms of action capable of controlling weed biotypes resistant to herbicides used in conventional water-seeded rice. Evaluated rice establishment systems included 1) conventional water-seed rice, 2) conventional drill-seeded rice, 3) water-seeded rice after spring tillage and a stale seedbed, 4) water-seeded rice after a stale seedbed without spring tillage, and 5) drill-seeded rice after a stale seedbed without spring tillage. Species composition of weed communities were distinctly different among establishment systems, as the water-seeded systems were dominated by sedge and broadleaf weed species but the drill-seeded systems were dominated by grass weed species. In the drill-seeded systems, grass control from pendimethalin and cyhalofop-butyl was higher than 85%. Glyphosate used in the stale seedbed systems greatly reduced post rice emergence weed densities in the water and drill-seeded systems. Rice yields did not differ among these establishment systems. Therefore, the alternative rice establishment systems evaluated in this study may be used to effectively manipulate weed species recruitment and enable the use of herbicides that may control weed biotypes resistant to herbicides used in conventional water-seeded systems.

Resistant watergrass testing continues as a service to California rice growers. Testing has been done for Ordram, Bolero, Regiment, Clincher and Propanil. Additional herbicides that may be added are: Cerano, Granite and Prowl. This service is performed during the winter in order to deliver results to the growers by planting time in the spring.