COMPREHENSIVE RICE RESEARCH

ANNUAL REPORT
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PROJECT TITLE: Weed Control in Rice

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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. 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 and ecophysiological opportunities to minimize herbicide costs and environmental impacts. To continue work on stale seedbed optimization for herbicide resistance management including development of a weed germination and emergence prediction approach.

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

5. To investigate new weed threats to California rice production.

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 on the Rice Experiment Station (RES) in Butte County (two sites), and at a farmer's field in Glenn County (one site). This year, the Butte County sites were planted on May 24 and June 7, with M-205. The Glenn County site was planted May 22 with M-104. At one of the Butte County (RES) locations, there is resistant smallflower umbrellasedge (to Londax, or bensulfuron-methyl). The Glenn County site has multiple-resistant late watergrass ("mimic"), which is resistant to thiobencarb and many of the sulfonylurea herbicides. Tolerance to clomazone has also been noted.

Due to variations in growing and irrigation methods utilized by farmers around the state of California, we continue to test herbicides in a variety of different settings, including continuous flood, pin-point flood, Leather's method, and dry/drill-seeding with flush irrigation. Continuously flooded plots are seeded into flooded fields, and water levels are maintained at approx. 4-6 inches throughout the season; water is drained at about a month before harvest, to facilitate machine harvest. Pin-point plots are also flooded at seeding, but water is drained at a specific point to allow for foliar application of herbicide. This year, water was drained at the 3-4 leaf stage of rice. Leather's method plots were seeded into the water as well, but water was drained earlier than in the pin-point method. One method leaves the water off the field until foliar herbicides can be applied, while the other method returns the water after the initial pegging of the seed followed immediately with water active herbicides. The seed for dry- or drill-seeded experiments was drilled into the soil, and the field was then flushed repeatedly to establish the rice (rice will emerge through soil or water, but not both). After the rice reached the 3-4 leaf stage, the fields were flooded with 4-6 inches of water.

All foliar herbicide applications were made with a CO_2-pressurized (207 kPa) hand-held sprayer equipped with a ten-foot boom and 8003 nozzles, calibrated to apply 187 liters spray volume per hectare (20 gallons/acre). Applications with solid formulations were performed by evenly broadcasting the product over the plots. In this report we mention the herbicides by their brand name and the herbicide rates appear as amounts of active ingredient; a cross-reference between brands and active ingredients is presented in Table 1.

1.1. Continuous-flood system combinations

In the continuously flooded trial, good weed control can be achieved with early treatments and best results were obtained when herbicide programs provided at least 95% of broad-spectrum weed control during the first month after seeding enabling recovery of about 20% of potential yield losses. Figure 1 depicts the effects of competition by different weed infestation levels (weed cover) on rice yields for seasons 2007 through 2012. Yields are expressed as percent of the best yields attained in this system. Weed cover in herbicide-treated plots compared to the untreated checks relates to the weed control exerted (Figure 1). Therefore, strong reduction in relative weed cover (percent of field area covered by weed foliage) corresponds to a high level of weed control, and the greatest weed cover % in Figure 1 (and in Figures 2 and 3) generally correspond to untreated control plots. The first month after seeding corresponds to the "critical" period of weed control (30 days after seeding) for flooded rice in California (Gibson et al. 2002)[1]. Treatments that consisted of an early application followed by a late-season treatment (4 lsr to 1 tiller) generally were no better than the best early treatments; however, they can be useful to prevent growth and seed production by late-emerging weeds and improve ease of harvest. Three separate trials were conducted, one with combinations based on previously tested herbicide combinations, one testing a granule formulation of Clincher, and one testing benzobicyclon.

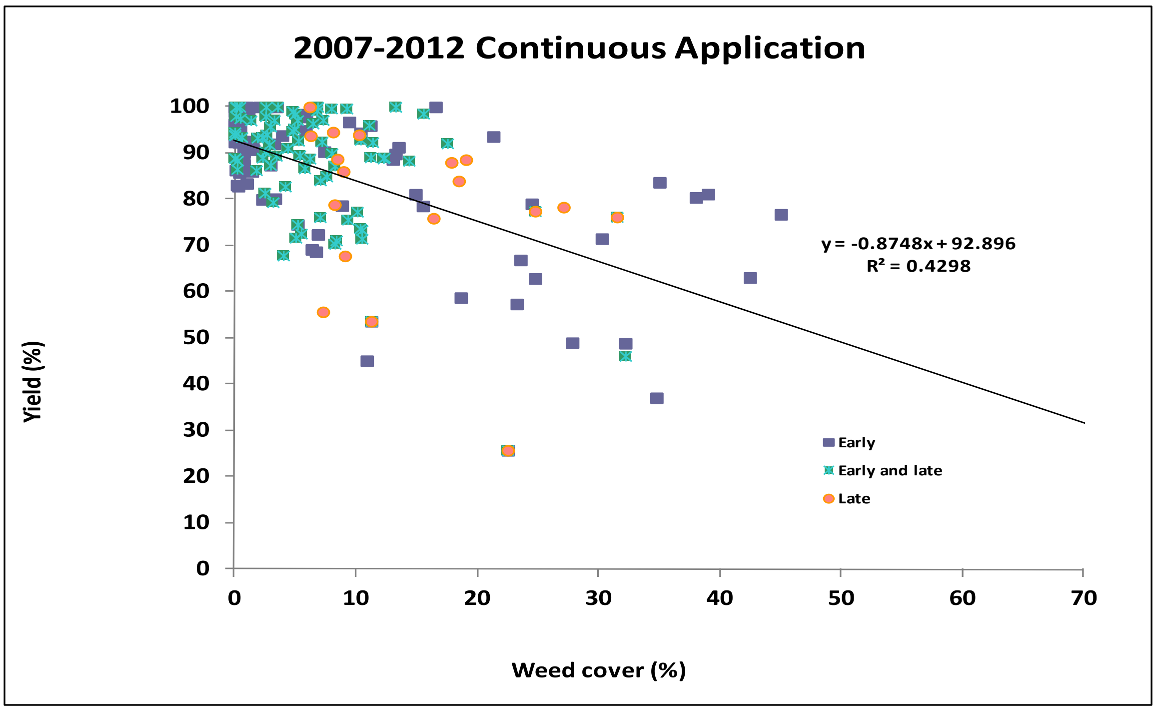


Figure 1. Weed competition in continuously flooded rice: Rice yields (percent of the maximum yield) as affected by weed cover (a measure of the intensity of weed infestation); evaluations of weed infestation were conducted 40 days after seeding rice. Data are combined for the 2007 through 2012 continuously flooded experiments at the RES. "Early" and "Late" refer to applications made near the 3 lsr and 1-3 tillers of rice, respectively.

[1]Gibson, K.D., A.J. Fischer, T.C. Foin and J.E. Hill.2002. Implications of delayed *Echinochloa* germination and duration of competition for integrated weed management in water-seeded rice. Weed Research 42:351-358.

The relatively low R^2 of the regressionin Figure 1 is mostly due to the slope of the line not being too steep and thus changes in weed cover were not associated with drastic changes in rice yields, which underscores the weed suppressive effect of the continuous presence of a 4-6 in deep flood in the field. In addition, herbicide treatments in this system provided very good control of watergrass and the remaining weed cover is represented by aquatic weeds (Table 2) that are not competing very strongly with rice. Other competitive grasses, such as sprangletop and barnyardgrass are normally not a problem in this system, since their emergence can be well suppressed by the continuous flooding. This all means that water-seeded and continuously flooded systems offer the best opportunities for choosing economic weed control programs if weed infestations are not excessive.

Testing of the new clomazone formulation Bombard, was continued this season. It is a prilled formulation, instead of an extruded, granule (Cerano). Efficacy on grasses appear to be about the same as Cerano and yields of field rate treatments were not statistically different for the two formulations of clomazone (Table 2). Bombard followed by Granite GR applied at both DOS and 1 lsr had almost 100% control across all weeds at 30 days after application. Cerano followed by Granite GR also had almost 100% control of all weeds, at both application timings as well. Bolero followed by propanil + Halomax or + Londax had excellent control of all weeds by two months after seeding and yields were among the highest in this trial at over 8,000 lb/A. The Cerano (at the 1 leaf stage of rice) followed by Granite GR also had an equivalent yield, along with the Bolero followed by Regiment and Cerano followed by propanil treatments, all of which had yields over 8000 lb/A. By seven days after the second application, none of these treatments exhibited phytotoxicity to rice.

<u>Gowan Demonstration Trial</u>

In a separate trial (Table 3), we tested a new active ingredient (benzobicyclon) that Gowan Company is pursuing for registration in California rice. We have been testing this compound for several years with good results. It is very effective on sedges and many broadleaf weeds with some activity on grasses.

There were two formulations of benzobicyclon applied in this trial. GWN-10146 is a granular formulation of benzobicyclon and halosulfuron, and 7.4 lb/A of product delivers 250g ai/ha benzobicyclon and 52.5g ai/ha halosulfuron. GWN-9796 is a liquid suspension formulation consisting of 6% benzobicyclon.

GWN-9796 alone, GWN-9796 and other herbicides as well as GWN-10146 (granule) alone had complete bulrush control (100%). Ducksalad was also well controlled by all of the herbicide combinations.

GWN-9796 and Sandea tank mix followed by Granite SC; Cerano followed by GWN-9796 and Sandea tank mix; GWN-9796 and Sandea tank mix followed by Clincher; and Cerano followed by GWN-9796 had the best watergrass control (over 85%). GWN-9796 followed by Grandstand had almost no watergrass control (6%). The GWN-9796 + Sandea tank mix followed by Regiment and GWN-10146 had good watergrass control.

Control of watergrass was better with the formulated granular mixture (GWN-10146) than with the GWN-9796 + Sandea tank mix.

Phytotoxicity was generally low, although there was some stunting observed in the Cerano followed by GWN-9796, and the Cerano followed by GWN-9796 + Sandea tank mix. Rice density counts and rice height measurements made at 30 days after treatment were not significantly different across all treatments (data not shown).

The highest yield in this trial was the GWN-9796 and Sandea tank mix followed by Granite SC, with 8474 lb/A. The lowest yield was in the GWN-9796 followed by Grandstand plot, which had a yield of only 1958lb/A, possibly due to the fact that 0% control of watergrass, and 100% control of bulrush allowed the watergrass to outcompete the rice. This trial was conducted in a portion of the field where the grass seedbank has been historically high.

<u>DOW Continuous Flood Granule Formulation Trial</u>
Shark was used in this trial to remove non-grass weeds to better assess the performance of this grass herbicide. In general, the Clincher granule formulation GF 2803 had better control than GF 2802 across all application rates (Table 4). Watergrass control increased with the rate of active ingredient (cyhalofop) in both formulations. GF 2803 followed by Granite GR had better control of watergrass and bulrush than the same rate of GF 2803 followed by Shark H2O. GF 2803 followed by Granite GR provided the best control of all weeds (near 100%).

1.2. Herbicide combinations for the Pin-point system
Often, cold weather or windy conditions in spring, or the need to use foliar-applied herbicides, require early field drainage to favor rice establishment and foliage exposure to the spray. Prevailing weeds in this experiment were early and late watergrass, ricefield bulrush, ducksalad and waterhyssop (Table 5).

Weed infestations in our pin-point plots have a stronger impact on yields compared with the continuously flooded system (Figures 1 and 2), because of the temporary elimination of the weed suppressive effect of flooding and the consequent encouragement of vigorous grass growth. This promotes weed emergence and competition, thus the steeper negative slope of the weed cover-yield relationship illustrated in Figure 2.

The pinpoint trial (Table 5) was managed by draining the water on June 22, approximately 14 days after seeding, when the rice was at the 1-2 leaf stage. It was re-flooded June 28 with rice past the 4 leaf stage. All initial applications were made at the 3-4 leaf stage of rice, while follow-up applications were made at the 1-2 tiller stage of rice.

By 30 days after application, the synergistic (Fischer et al. (2004) Weed Biology and Management 4:206-212) tank mix of Abolish (3363g ai/ha) plus Regiment (30g ai/ha) had good control of watergrass (95%), bulrush (85%) and ducksalad (91%). Likewise, Regiment alone had only fair control of all weeds, but Regiment followed by SuperWham (6 qt/A) at the 1-2 tiller stage of rice had good control of watergrass (99%), bulrush (78%), and ducksalad (89%), by 30 days after application.

The best control and yields in this trial were from Granite SC (2 oz/A) alone, or a Granite SC + Clincher tank mix followed by SuperWham (6 qt/A). All had good control of watergrass (over 99%), and ducksalad (over 92%) at 30 days after initial application. Bulrush control was best with Granite SC alone (100%), whereas the Clincher tank mix offered only 88% control. Yields were approximately 7600 lb/A, the highest in this trial. The sequential of Clincher followed by SuperWham continues to perform well overall, consistent with results of previous years. SuperWham applied at the 1-2 tiller stage of rice was a better timing for bulrush control than the earlier 3-4 lsr application.

Leathers' Method Foliar herbicides

The Leather's method trial (Table 6) was managed by draining the water on June 20, approximately 13 days after seeding, when the rice was at the 1-2 leaf stage. It was re-flooded June 25. All initial applications were made at the 2-3 leaf stage of rice, while follow-up applications were made at the 1-2 tiller stage of rice.

All herbicide combinations: Clincher + Granite SC tank mix followed by SuperWham (13oz/A and 2oz/A followed by 6 qt/A); Clincher followed by Ultra Stam 80 EDF (15oz/A followed by 7.4lb/A); Super Wham + Clincher tank mix (4qt/A and 15oz/A); Regiment followed by Super Wham (0.54oz/A followed by 6qt/A); and Regiment + Abolish tank mix (0.54oz/A and 1.5qt/A) had good watergrass control (over 95%). Bulrush was also well-controlled (over 91%) by all combinations except for the Regiment (.54 oz/A) and Abolish (1.5 qt/A) tank mix (47%).

The highest yield (8139lb/A) was in the Clincher + Granite SC tank mix followed by SuperWham.

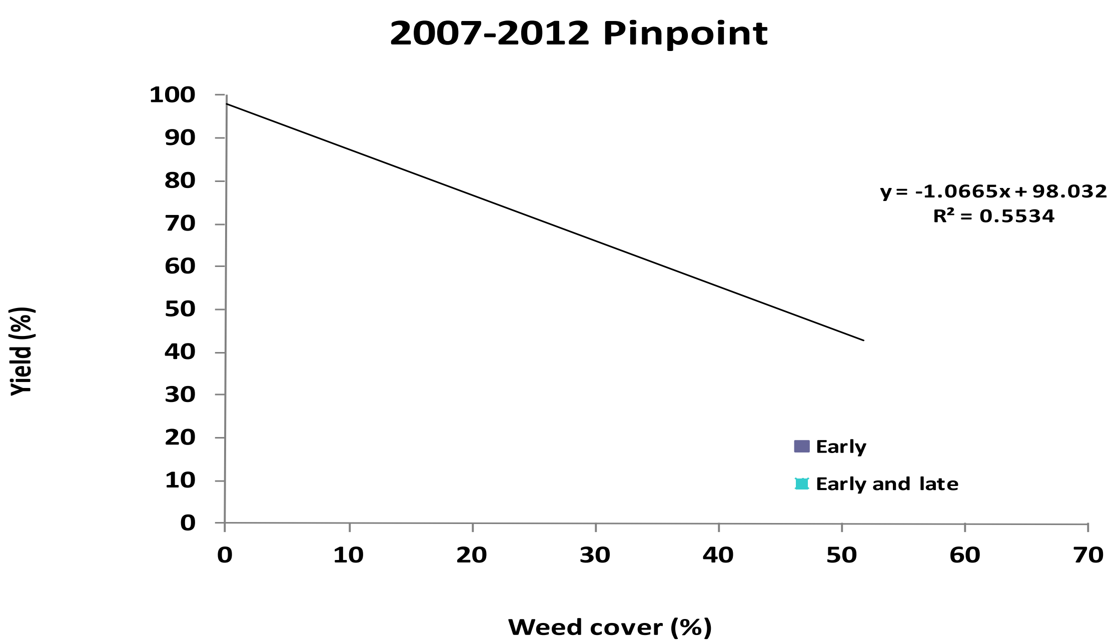


Figure 2. Weed competition in pin-point flooded rice: Rice yields (percent of the maximum yield) as affected by weed cover (a measure of the intensity of weed infestation); evaluations of weed infestation were conducted 40 days after seeding rice. Data are combined for the 2007 through 2012 pinpoint flooded experiments at the RES. Early and late refer to applications made near the 3 lsr and 1-3 tillers of rice, respectively.

Leathers' Method for granular formulations of benzobicyclon

A separate trial (Table 7), using benzobicyclon in a Leathers' method, was conducted to assess its effectiveness in different irrigation systems (in past trials, it was only utilized in a continuous flood). The trial was seeded June 4, and the drain was started June 11. The plots were completely drained by June 13. The re-flood was started gradually when rice was ¼ inch pegged into the soil and by June 15, with rice at the 1-1.5 leaf stage, water was 3-4 inches deep. Applications were applied day-of-seeding (DOS), and/or soon post re-flood (June 18).

There were two formulations of benzobicyclon applied in this trial. GWN-10146 is a granular formulation of benzobicyclon + halosulfuron, and 7.4 lb/A of product delivers 250g ai/ha benzobicyclon and 52.5g ai/ha halosulfuron. GWN-9796 is a liquid suspension formulation consisting of 6% benzobicyclon.

The liquid suspension formulation GWN-9796 (57 oz/A) + Sandea (1 oz/A), and the combination granule GWN-10146 (7.4 lb/A) gave excellent bulrush, watergrass and ducksalad control when applied at both day-of-seeding and post re-flood. GWN-9796 alone did not provide significant watergrass control, especially when applied post re-flood. For all treatments, yields were higher when the applications were made day-of-seeding.

Initial phytotoxicity symptoms had mostly disappeared by 14 days after post re-flood treatments, but 4-16% stand reduction was still visually quantifiable for the day-of-seeding applications. Rice density counts and rice height measurements made at 30 days after treatment were not significantly different across all treatments (not shown).

1.3. Drill seeded system

This is the system that offers flexibility for herbicide use when proximity to sensitive crops imposes restrictions to aerial applications. Drill seeding favors weeds adapted to dryland seedbeds (sprangletop is typically problematic) but is unfavorable for the recruitment of aquatic species (ricefield bulrush, ducksalad, redstem). Thus drill seeding is useful for alternation with water-seeded systems when the pressure of aquatic weeds becomes problematic.

Weed competition can cause significant yield loss under drill seeding, and early-applied treatments providing greater than 95 % weed control were necessary for optimum yields (Figure 3). As mentioned earlier, low weed cover is associated with high weed control in these experiments. Main weeds in the experiment were the *Echinochloa* complex and sprangletop (Table 8).

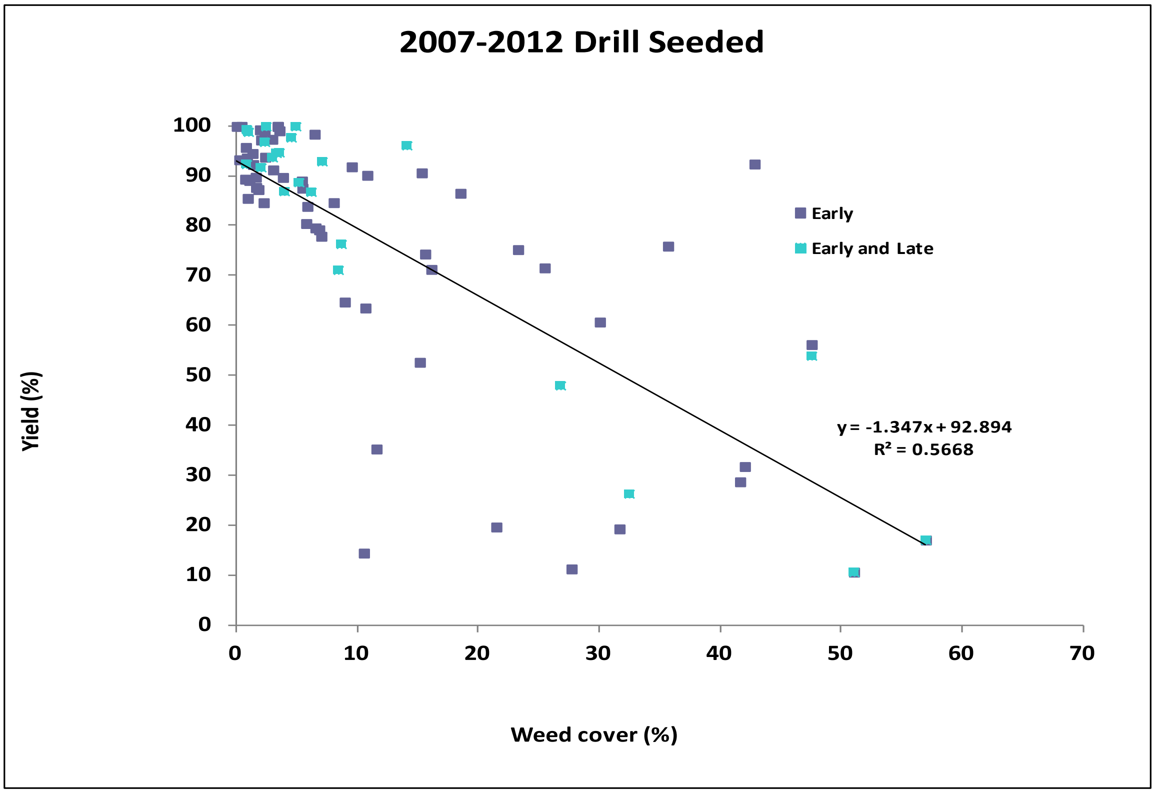


Figure 3. Weed competition in drill seeded rice; evaluations of weed infestation were conducted 40 days after seeding rice. Rice yields (percent of the maximum yield) as affected by weed cover (a measure of the intensity of weed infestation). Data are combined for the 2007 through 2012 drill seeded experiments at the RES. Early and late refer to applications made near the 3 lsr and 1-3 tillers of rice, respectively.

The Prowl H2O (2 pt/A) treatment applied as a delayed pre-emergent (one week after seeding) had controlled watergrass (77%) and sprangletop (75%) by 30 days after application with a yield of 5930 lb/A. When followed by SuperWham at the 3-4 lsr (4 qt/A)the control of watergrass was much higher (97%) and yields were higher (6949 lb/A). Control of sprangletop was the same (75%), since propanil has little activity on this weed.

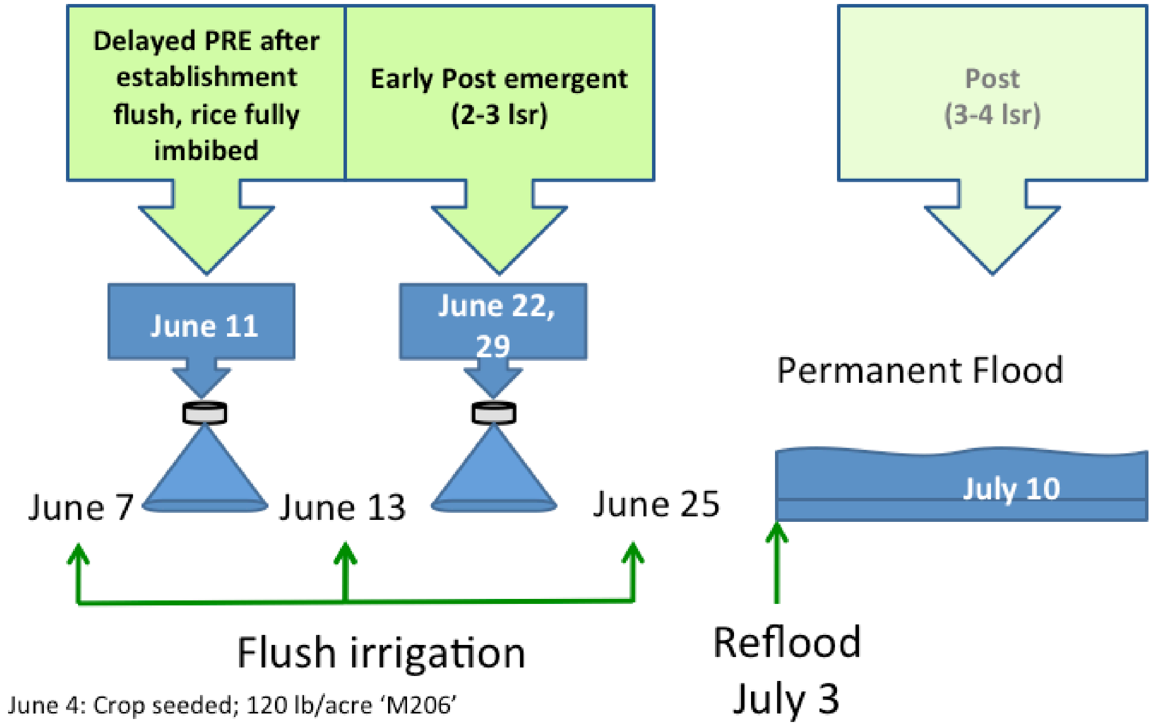


Figure 4. Timings for herbicide applications in drill seeded rice. Dates correspond to applications in 2012 following the June 4 seeding of 'M-206' rice (DPRE = delayed pre-emergence; lsr = leaf stage of rice).

Objective 2: 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.

Bombard

Bombard is a new formulation of clomazone. It has the same percent active ingredient as Cerano and will be applied at identical rates. The formulation is a prilled granule instead of an extruded granule like Cerano. Weed suppressive activity and yield appear to be similar to Cerano applied at label rates (Table 2). Slightly higher yields were realized when clomazone (both formulations) was applied at the one leaf stage of rice growth and followed by Granite GR.

V-10219

Valent has been researching the potential for a combination granule of thiobencarb and imazosulfuron (V-10219) to be used in California rice production. It will apparently be named League MVP. It has delivered excellent broad-spectrum control, including consistent ricefield bulrush control, with excellent yields over several years of testing, and was tested this year in an herbicide-resistant watergrass site (Table 16).

Butte

Gowan Company has been researching the potential for foliar-applied benzobicyclon (GWN-9796) to be used in California rice production. It has recently developed granular formulations as well (GWN-10146, is a combination granule with halosulfuron).

Benzobicyclon has been used in Japanese rice production for a number of years. It is a different mode of action than the other available herbicides in California. It is efficacious on bulrush, smallflower umbrellasedge, ducksalad and monochoria. In addition, it also has some activity on sprangletop and watergrass (Tables 3, 7). Although it has good residual activity it will not be a stand-alone chemical and therefore will need to be backed up by other herbicide options in a program. Gowan is working on a granular formulation for the California market that will likely be combination granule GWN-10146 mentioned above.

Table 1. Herbicides used and their active ingredient

Brand name	**Active ingredient**
Abolish	thiobencarb
Bolero Ultramax	thiobencarb
Cerano	clomazone
Bombard	clomazone
Clincher CA	cyhalofop-butyl
Clincher granule	cyhalofop-butyl
Granite SC	penoxsulam
Granite GR	penoxsulam
Grandstand CA	triclopyr
Londax	bensulfuron methyl
Prowl H_2O	pendimethalin
Regiment CA	bispyribac-sodium
Shark H_2O	carfentrazone
Stam 80 EDF-CA	propanil
Superwham! CA	propanil
Whip 360	fenoxaprop-p-ethyl
Roundup	glyphosate
Halomax 75	halosulfuron-methyl
RiceShot 48 SF	propanil
Sandea	halosulfuron-methyl
V-10219 (League MVP)	thiobencarb + imazosulfuron
GWN-9796	benzobicyclon

Table 2. Continuous flood system for rice.

Treatment	Rate (g ai/ha)	Rate Prod./a	Timing[3]	Application date 1st	Application date 2nd	Phytotoxicity[1] 1st 7 DAT % Stunting	1st 7 DAT % Stand	1st 7 DAT % Injury	1st 14 DAT % Stunting	1st 14 DAT % Stand	1st 14 DAT % Injury	2nd 7 DAT % Stunting	2nd 7 DAT % Stand	2nd 7 DAT % Injury	2nd 14 DAT % Stunting	2nd 14 DAT % Stand	2nd 14 DAT % Injury	Weed Control[2] 13-Jun ECHPH	13-Jun SCPMU	13-Jun HETLI	9-Jul ECHPH	9-Jul SCPMU	9-Jul HETLI	9-Jul BAORO	23-Jul ECHPH	23-Jul ECHOR	23-Jul SCPMU	Yield (lb/A) 9-Oct
Untreated[4]	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	5	2	6	13	4	5	5	1	22	4076
Cerano	673	12lb	DOS	24-May	—	NA	NA	NA	1	4	7	—	—	—	—	—	—	36	10	64	85	0	62	0	81	100	0	4773
Bombard	673	12lb	DOS	24-May	—	NA	NA	NA	1	1	2	—	—	—	—	—	—	18	3	44	78	0	57	14	74	100	0	5565
Bombard fb. Granite GR	673 fb. 40	12lb fb. 15lb	DOS fb 2.5 lsr	24-May	11-Jun	NA	NA	NA	0	14	0	0	4	0	0	4	1	0	41	70	98	97	98	98	97	100	98	7188
Bombard fb. Granite GR	673 fb. 40	12lb fb. 15lb	1 lsr fb 2.5 lsr	5-Jun	11-Jun	0	0	16	0	0	13	0	1	7	0	1	4	41	58	78	99	100	100	100	100	100	100	7926
Cerano fb. Granite GR	673 fb. 40	12lb fb. 15lb	DOS fb 2.5 lsr	24-May	11-Jun	NA	NA	NA	0	16	2	0	3	0	0	4	1	30	40	88	97	100	100	98	96	100	100	6913
Cerano fb. Granite GR	673 fb. 40	12lb fb. 15lb	1 lsr fb 2.5 lsr	5-Jun	11-Jun	0	0	8	0	0	6	0	0	6	0	0	2	24	35	64	99	100	100	100	99	100	99	8266
Granite GR	40	15lb	2.5 lsr	11-Jun	—	0	4	0	0	6	1	—	—	—	—	—	—	0	17	68	93	99	97	100	84	100	99	6939
Cerano	560	10lb	DOS	24-May	—	NA	NA	NA	0	6	0	—	—	—	—	—	—	0	12	52	55	0	35	0	55	100	0	6575
Cerano fb. Shark H2O + Halomax	560 fb. 196 + 68	10lb fb. 7oz + 1.3oz	DOS fb. 2-3 lsr	24-May	11-Jun	NA	NA	NA	0	3	2	1	3	0	0	2	0	23	58	81	97	100	82	99	94	100	100	6892
Cerano fb. Shark H2O + Londax	560 fb. 196 + 70	10lb fb. 7oz + 1.66oz	DOS fb. 2-3 lsr	24-May	11-Jun	NA	NA	NA	1	6	2	0	3	0	0	3	0	0	48	85	94	95	100	100	91	100	100	7949
Cerano fb. Shark H2O	560 fb. 196	10lb fb. 7oz	DOS fb. 2-3 lsr	24-May	11-Jun	NA	NA	NA	1	13	1	0	4	0	0	4	0	0	46	89	65	90	92	73	34	100	81	7513
Untreated[4]	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3	7	3	7	15	6	4	7	1	25	3838
Bolero fb. Propanil + COC	3918 fb. 6726 + 1.25%	23.3lb fb. 6qt + 1.25%	1-2 lsr fb. 1-2 tiller	5-Jun	5-Jul	0	0	0	0	0	0	0	1	2	0	1	0	0	55	68	75	83	65	100	92	100	97	8073
Bolero fb. Propanil + Halomax + COC	3918 fb. 6726 + 68 + 1.25%	23.3lb fb. 6qt + 1.30z + 1.25%	1-2 lsr fb. 1-2 tiller	5-Jun	5-Jul	0	0	0	0	0	0	0	0	2	0	0	1	0	86	84	72	81	51	100	98	100	100	8151
Bolero fb. Propanil + Londax + COC	3918 fb. 6726 + 70 + 1.25%	23.3lb fb. 6qt + 1.660z + 1.25%	1-2 lsr fb. 1-2 tiller	5-Jun	5-Jul	0	0	0	0	0	0	0	0	3	0	0	1	0	65	73	75	73	65	100	99	100	99	8318
Bolero	3918	23.3lb	1-2 lsr	5-Jun	—	0	0	0	0	0	0	—	—	—	—	—	—	0	71	78	71	87	54	100	64	100	67	7411
Shark H2O + Granite GR	224 + 40	8oz + 15lb	2.5 lsr	11-Jun	—	0	3	0	1	4	0	—	—	—	—	—	—	22	48	58	97	98	100	99	98	100	98	7851
Granite GR fb. SuperWham + COC	40 fb. 6726 + 1.25% v/v	15lb fb. 6qt + 1.25% v/v	2.5 lsr fb. 1-2 tiller	11-Jun	5-Jul	0	3	0	0	4	1	1	6	2	7	7	0	0	23	35	98	100	100	96	97	100	100	7350
Shark H2O fb. SuperWham + COC	224 fb. 6726 + 1.25% v/v	8oz fb. 6qt + 1.25% v/v	1-2 lsr fb. 1-2 tiller	5-Jun	5-Jul	0	15	0	0	14	0	0	3	2	3	3	0	9	54	66	0	56	70	43	2	100	93	7258
V-10219 fb. Regiment + UAN + NIS	3508 fb. 22.4 + 2.0% + 0.2% v/v	30lb fb. 0.4oz + 2.0% + 0.2% v/v	2 lsr fb. 1-2 tiller	11-Jun	5-Jul	0	2	0	0	2	0	0	5	1	4	3	1	24	19	28	0	34	21	0	79	100	92	7437
Bolero fb. Regiment + UAN + NIS	3918 fb. 22.4 + 2.0% + 0.2% v/v	23.3lb fb. 0.4oz + 2.0% + 0.2% v/v	1-2 lsr fb. 1-2 tiller	5-Jun	5-Jul	0	0	0	0	0	0	0	0	0	0	0	0	0	60	56	79	88	64	100	98	100	99	8111
Cerano fb. Propanil + COC	673 fb. 6726 + 1.25%	12lb fb. 6qt + 1.25%	DOS fb. 1-2 tiller	24-May	5-Jul	NA	NA	NA	0	8	2	0	1	2	1	1	1	0	19	51	61	25	56	0	83	100	94	8149
Bolero fb. Granite GR	3918 fb. 40	23.3lb fb. 15lb	1-2 lsr fb. 2-3 lsr	5-Jun	11-Jun	0	13	0	0	8.8	0	0	6	1	0	7	1	14	67	96	97	94	98	100	98	100	98	6960
LSD (P=0.05)																												1226

[1] % Stand (percent stand reduction), % Stunting (percent stunting of rice), % Injury (percent injury to rice)

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

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

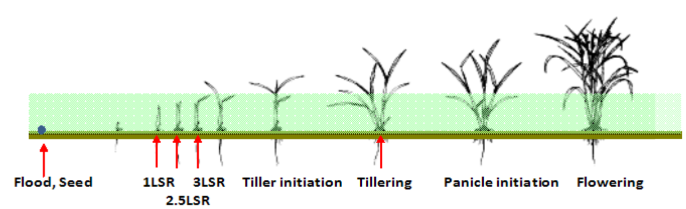
[4] Untreated weed control values represent % cover by the respective weed species

[5] V-10219 consists of 10% thiobencarb + 0.46% imazosulfuron

Trial Information

1. Trial seeded May 24, 2012 with 120 lbs per acre of M205
2. Trial managed as a permanent flood with flood water at 3-4 inches.
3. No weeds were visible when Cerano was applied on day of seeding May 24.
   Watergrass was 2-3 leaf, bulrush and ducksalad were 2-3 leaf on June 5.
   Watergrass was 3-4 leaf, ricefield bulrush was 3 leaf, smallflower was 1-2 leaf and ducksalad was 3 leaf on June 11.
   Watergrass and ricefield bulrush were 2 tillers, monochoria was 2 leaf, arrowhead was 1-2 leaf, and ducksalad and hyssop were flowering on July 5.
4. Spray applications made with 20 gallons/acre using 8003 nozzles.
5. Weather conditions on May 24: Air temperature 63° F, water temperature 67° F wind 3.5 MPH from the southeast.
   Weather conditions on June 5: Air temperature 75° F, wind 4 MPH from the northwest.
   Weather conditions on June 11: Air temperature 73.2° F, wind 2.4 MPH from the south.
   Weather conditions on July 5: Air temperature 65.4° F, water temperature 70.7° F, wind 6.5 MPH from the southeast.
6. May 19, 2012 - 150lb ammonium sulfate = 30lb nitrogen/acre

Continuous Flood



Application timing

Flood: May 24, 3-4" water depth

Day of Seeding Application: May 24

Post-Flood Applications: June 5, June 11, July 5

Table 3. Continuous flood programs for benzobicyclon.

Treatment	Rate		Timing[3]	Date		Phytotoxicity[1]												Weed Control[2]									
						1st						2nd															
						% Stand	% Stunting	% Injury	% Stand	% Stunting	% Injury	% Stand	% Stunting	% Injury	% Stand	% Stunting	% Injury	ECHPH	SCPMU	HETLI	ECHPH	SCPMU	HETLI	ECHPH	SCPMU	HETLI	Yield (lb/A)
	(g ai/ha)	Prod./a		1st	2nd	7 DAT			14 DAT			7 DAT			14 DAT			13-Jun			6-Jul			23-Jul			9-Oct
Untreated[4]	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3	8	5	22	4	8	35	7	4	2237
GWN-9796 + Sandea	250 + 52.5	57oz + 1oz	1 lsr	4-Jun	–	0	3	4	0	3	3	–	–	–	–	–	–	17	74	68	35	100	74	44	100	68	5671
GWN-9796 fb. Grandstand + COC	250 fb. 420 + 1.25% v/v	57oz fb. 1pt + 1.25% v/v	1 lsr fb. 3-4 lsr	4-Jun	28-Jun	0	5	6	0	6	1	0	0	0	0	0	0	0	51	51	6	100	76	0	100	56	1958
GWN-10146	250 + 52.5	7.4 lb	1 lsr	4-Jun	–	0	0	1	0	1	1	–	–	–	–	–	–	0	81	78	81	100	92	79	100	88	5886
GWN-9796 + Sandea fb. SuperWham + COC	250 + 52.5 fb. 4484 + 1.25% v/v	57oz + 1oz fb. 4qt + 1.25% v/v	1 lsr fb. 3-4 lsr	4-Jun	28-Jun	0	0	2	0	0	1	0	2	2	0	0	0	34	84	87	74	100	86	56	100	72	5439
GWN-9796 + Sandea fb. Regiment + NIS	250 + 52.5 fb. 30 + 0.125% v/v	57oz + 1oz fb. 0.54oz + 0.125% v/v	1 lsr fb. 3-4 lsr	4-Jun	28-Jun	0	5	3	0	0	2	1	2	9	1	2	0	37	84	71	66	100	83	97	100	75	6193
GWN-9796 + Sandea fb. Granite SC + COC	250 + 52.5 fb. 35 + 1.25% v/v	57oz + 1oz fb. 2oz + 1.25% v/v	1 lsr fb. 3-4 lsr	4-Jun	28-Jun	0	0	0	0	0	2	0	0	1	1	0	0	26	88	83	89	100	92	97	100	94	8474
Cerano fb. GWN-9796 + Sandea	673 fb. 250 + 52.5	12lb fb. 57oz + 1oz	DOS fb. 1 lsr	24-May	4-Jun	NA	NA	NA	0	9	1	0	13	2	0	4	4	83	84	100	95	100	96	93	100	98	7403
GWN-9796 + Sandea fb. Clincher + COC	250 + 52.5 fb. 315 + 1.25%	57oz + 1oz fb. 15oz + 1.25%	1 lsr fb. 3-4 lsr	4-Jun	28-Jun	0	0	2	0	0	2	0	0	1	0	0	0	0	78	67	90	100	87	98	100	87	7693
Cerano fb. GWN-9796	673 fb. 250	12lb fb. 57oz	DOS fb. 1 lsr	24-May	4-Jun	NA	NA	NA	0	15	3	0	18	3	0	10	0	72	33	93	92	100	98	90	100	92	6476
LSD (P=0.05)																											1421

[1] % Stand (Percent stand reduction), % Stunting (Percent stunting of rice), % Injury (percent injury to rice)

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

[3] fb. (followed by), PFS (pre-flood surface), PWE (pre-weed emergence), lsr (leaf stage of rice), Til (tillers of rice).

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

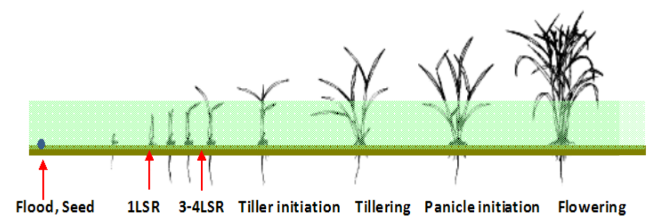
Trial Information

1. Trial seeded May 24, 2012 with 120 lbs per acre of M205
2. Trial managed as a continuous flood with 3-4 inches.
3. No weeds visible on May 24.
   Watergrass was 2 leaf, ricefield bulrush and ducksalad had sprouted on June 4
   Watergrass was 1-2 tillers, ricefield bulrush was 2 tillers, duscksalad had early buds, redstem was 6-8 leaves, hyssop was pre-bud, and arrowhead was 3 leaf on June 28.
4. Liquid applications of GWN-9796 made with 10 foot boom with nozzles removed.
5. Weather conditions on May 24: Air temperature 63° F, water temperature 67° F, wind 3.5 MPH from the Southeast.
   Weather conditions on June 4: Air temperature 64° F, water temperature 63° F, wind 9 MPH from the South.
   Weather conditions on June 28: Air temperature 94° F, water temperature 93° F, wind 1 MPH from the Southwest.
6. May 19, 2012 - 150lb ammonium sulfate = 30lb nitrogen/acre

GWN-10146 is a granular formulation of benzobicyclon and halosulfuron. 7.4lb/a of product delivers 250g ai/ha benzobicyclon and 52.5g ai/ha halosulfuron.
GWN-9796 is a liquid suspension formulation consisting of 6% benzobicyclon
Sandea is a granular formulation of 75% halosulfuron.

All applications containing GWN-9796 were made with a 10ft spray boom with nozzles removes to simulate a direct stream application.
All granular formulations were hand dispersed across plot area.

Continuous Flood benzobicyclon programs



Application timing

Flood: May 24, 3-4" water depth

Day of Seeding Application: May 24

Post-Flood Applications: June 4, June 28

Table 4. Continuous flood trial testing Clincher granule.

Treatment	Rate		Timing[3]	Application date		Phytotoxicity1						Weed Control[2]										Yield (lb/A)
						% Stunting	% Stand	% Injury	% Stunting	% Stand	% Injury	ECHPH	SCPMU	HETLI	ECHPH	SCPMU	HETLI	ECHPH	SCPMU	HETLI	MOOVA	
	(g ai/ha)	Prod /a		1st	2nd	7 DAT			14 DAT			9-Jul			18-Jul			7-Aug				18-Oct
Untreated fb. Shark[4]	224	8 oz	2 lsr	22-Jun	—	—	—	—	—	—	—	5	4	9	21	4	21	23	4	2	6	4098
Cerano fb. Shark H2O	673 fb. 224	12lb fb. 8oz	1-2 lsr fb. 2 lsr	21-Jun	22-Jun	0	0	6	0	0	3	40	68	36	77	19	83	70	0	69	96	7339
Clincher G (GF 2802) fb. Shark H2O	200 fb. 224	10lb fb. 8oz	2.5-3.5 lsg fb. 2 lsr	21-Jun	22-Jun	0	0	1	0	0	1	26	54	41	60	14	85	44	0	63	95	6956
Clincher G (GF 2802) fb. Shark H2O	323 fb. 224	16lb fb. 8oz	2.5-3.5 lsg fb. 2 lsr	21-Jun	22-Jun	0	0	0	0	0	0	20	25	0	77	0	81	66	0	82	87	7951
Clincher G (GF 2802) fb. Shark H2O	404 fb. 224	20lb fb. 8oz	2.5-3.5 lsg fb. 2 lsr	21-Jun	22-Jun	0	0	1	0	0	1	62	39	32	83	7	71	84	0	92	90	7532
Clincher G (GF 2802) fb. Shark H2O	808 fb. 224	40lb fb. 8oz	2.5-3.5 lsg fb. 2 lsr	21-Jun	22-Jun	0	0	2	0	0	0	73	45	22	96	26	73	94	10	66	92	8635
Clincher G (GF 2803) fb. Shark H2O	323 fb. 224	8lb fb. 8oz	2.5-3.5 lsg fb. 2 lsr	21-Jun	22-Jun	0	0	1	0	0	0	33	59	5	70	17	72	64	0	90	89	7205
Clincher G (GF 2803) fb. Shark H2O	364 fb. 224	9lb fb. 8oz	2.5-3.5 lsg fb. 2 lsr	21-Jun	22-Jun	3	0	2	0	0	0	47	49	27	76	52	71	77	0	78	96	7786
Clincher G (GF 2803) fb. Shark H2O	404 fb. 224	10lb fb. 8oz	2.5-3.5 lsg fb. 2 lsr	21-Jun	22-Jun	0	1	2	0	0	1	43	56	50	81	0	64	80	0	77	81	7138
Clincher G (GF 2803) fb. Shark H2O	808 fb. 224	20lb fb. 8oz	2.5-3.5 lsg fb. 2 lsr	21-Jun	22-Jun	1	0	1	0	0	1	68	52	31	90	20	64	92	0	92	88	7672
Clincher G (GF 2803) fb. Granite GR	323 fb. 40	8lb fb. 15lb	2.5-3.5 lsg fb. 2 lsr	22-Jun	22-Jun	1	0	1	0	0	0	53	39	52	96	100	100	99	98	100	34	6888
Clincher + Shark H2O	285 fb. 224	13.6oz fb. 8oz	2.5-3.5 lsg fb. 2 lsr	22-Jun	—	NA	NA	NA	6	40	3	71	45	0	91	0	0	83	0	61	44	5010
																						1659

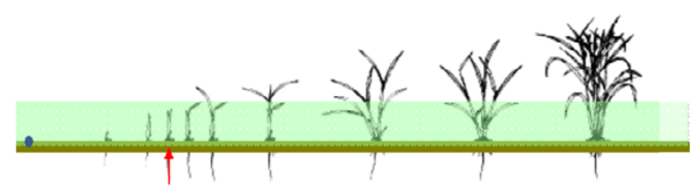
[1] % Stand (percent stand reduction), % Stunting (percent stunting of rice), % Injury (percent injury to rice)

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

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

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

Continuous Flood for Clincher granule



Application timing

Flood: June 7, 3-4" water depth

Post-Flood Applications: June 21, 22

Trial Information

1. Trial seeded June 7, 2012 with 120 lbs per acre of M206
2. Trial managed as a permanent flood with flood water at 3-4 inches.
3. Watergrass was 2 leaf, ricefield bulrush was 1-2 leaf, and ducksalad was 1-2 leaf on June 21.
   Watergrass was 2.5 leaf, ricefield bulrush was 2 leaf, ducksalad was 2 leaf and water hyssop was 2 leaf on June 22.
4. Spray applications made with 20 gallons/acre using 8003 nozzles.

   Weather conditions on July 21: Air temperature 72^{0} F, water temperature 71^{0} F, wind 6-7 MPH from the south.

   Weather conditions on June 22 (1st app.): Air temperature 61^{0} F, water temperature 62^{0} F, wind 10.3 MPH from the south.

   Weather conditions on June 22 (2nd app.): Air temperature 65^{0} F, water temperature 66^{0} F, wind 8 MPH from the southeast.
6. May 29, 2012 - 150lb ammonium sulfate = 30lb nitrogen
7. Note: Treatment 12 (Clincher fb Shark H2O) was combined into a tank mix and caused high phytotoxicity to the rice

Table 5. Pinpoint flood system.

Treatment	Rate (g ai/ha)	Rate Prod./a	Timing[3]	Date 1st	Date 2nd	Phytotoxicity[1] 1st 7 DAT % Stunting	1st 7 DAT % Stand	1st 7 DAT % Injury	1st 14 DAT % Stunting	1st 14 DAT % Stand	1st 14 DAT % Injury	2nd 7 DAT % Stunting	2nd 7 DAT % Stand	2nd 7 DAT % Injury	2nd 14 DAT % Stunting	2nd 14 DAT % Stand	2nd 14 DAT % Injury	Weed Control[2] 9-Jul ECHPH	9-Jul SCPMU	9-Jul HETLI	9-Jul BAORO	18-Jul ECHPH	18-Jul SCPMU	18-Jul HETLI	7-Aug ECHPH	7-Aug SCPMU	7-Aug HETLI	Yield (lb/A) 21-Oct
Untreated[4]	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3	5	8	4	13	2	30	24	1	1	3535
Clincher + Granite SC + COC fb. SuperWham + COC	280 + 35 + 2.5% v/v fb. 6726 + 2.5% v/v	13oz + 2oz + 2.5% v/v fb. 6qt + 2.5% v/v	3-4 lsr fb. 1-2 Til	27-Jun	10-Jul	1	0	1	0	0	0	0	1	2	0	4	0	11	0	18	0	100	88	92	99	100	75	7655
Granite SC + COC	35 + 2.5% v/v	2oz + 2.5% v/v	3-4 lsr	27-Jun	—	0	0	1	0	0	0	—	—	—	—	—	—	9	30	0	0	100	100	98	100	100	88	7696
Granite SC + Clincher + COC fb. SuperWham + COC	35 + 315 + 2.5% v/v fb. 6726 + 1.25% v/v	2oz + 15oz + 2.5% v/v fb. 6qt + 1.25% v/v	3-4 lsr fb. 1-2 Til	27-Jun	10-Jul	0	0	5	0	0	6	0	0	2	0	2	0	0	21	15	28	99	88	94	99	84	75	7640
Clincher + COC	315 + 2.5% v/v	15oz + 2.5% v/v	3-4 lsr	27-Jun	—	0	0	0	0	26	0	—	—	—	—	—	—	10	13	14	0	97	0	0	99	9	13	4244
Clincher + COC fb. SuperWham + COC	315 + 2.5% v/v fb. 6726 + 1.25% v/v	15oz + 2.5% v/v fb. 6qt + 1.25% v/v	3-4 lsr fb. 1-2 Til	27-Jun	10-Jul	0	0	0	0	0	0	0	0	0	0	3	0	0	24	17	9	99	78	89	96	72	0	5369
Untreated[4]	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	4	7	3	13	2	33	22	1	1	2723
SuperWham + Clincher + COC	4484 + 315 + 2.5% v/v	4qt + 15oz + 2.5% v/v	3-4 lsr	27-Jun	—	0	6	4	0	6	1	—	—	—	—	—	—	0	22	7	7	92	32	0	94	81	6	3536
Regiment + NIS	30 + 0.125% v/v	0.54oz + 0.125% v/v	3-4 lsr	27-Jun	—	1	3	5	0	2	2	—	—	—	—	—	—	35	27	2	14	87	67	79	86	88	44	6671
Regiment + NIS fb. SuperWham + COC	30 + .125% v/v fb. 6726 + 1.25% v/v	0.54oz + 0.125% v/v fb. 6qt + 1.25% v/v	3-4 lsr fb. 1-2 Til	27-Jun	10-Jul	3	4	8	0	4	6	0	5	3	0	16	0	9	27	17	0	99	78	89	98	72	63	5403
Abolish	3363	1.5qt	3-4 lsr	27-Jun	—	0	0	1	0	0	0	—	—	—	—	—	—	0	33	6	0	15	26	0	30	38	31	3056
Regiment + Abolish	30 + 3363	0.54oz + 1.5qt	3-4 lsr	27-Jun	—	4	15	9	1	13	4	—	—	—	—	—	—	11	32	15	6	95	85	91	98	94	63	5370
LSD (P=0.05)																												1000

[1] % Stand (percent stand reduction), % Stunting (percent stunting of rice), % Injury (percent injury to rice)

[2] 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)

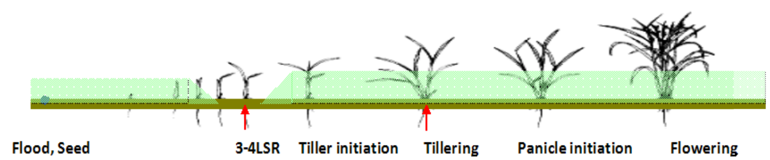
[3] PFS (pre-flood surface), PPI (pre-plant incorporated), fb. (followed by), lsr (leaf stage of rice), Til (tillers of rice).

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

Trial Information

1. Trial seeded June 7, 2012 with 120 lbs per acre of M206
2. Trial managed as a pinpoint flood with flood water drained June 22, reflood June 28.
3. Watergrass was 3 leaf, bulrush was 2 leaf, ducksalad was 4 leaf, smallflower was 1 inch on June 27.
   Watergrass was 2 tiller, bulrush was 1-2 tiller, ducksalad was flowering, smallflower was 6-8 leaf on July 10.
5. Spray applications made with 20 gallons/acre using 8003 nozzles.
6. Weather conditions on June 27: Air temperature 94° F, wind 2 MPH from the northwest.
   Weather conditions on July 10: Air temperature 79° F, water temperature 72° F, wind 0-1 MPH from the east.

Pinpoint Flood



<u>Application timing</u>

Flood: June 7, 3" water depth

Drained: June 22

1st Application: June 27

Reflood: June 28, 4" water depth

Post permanent flood applications: July 10

Table 6. Leathers method.

Treatment	Rate		Timing[3]	Date		Phytotoxicity[1] 1st						Phytotoxicity[1] 2nd						Weed Control[2]									
						% Stunting	% Stand	% Injury	% Stunting	% Stand	% Injury	% Stunting	% Stand	% Injury	% Stunting	% Stand	% Injury	ECHPT	SCPMU	HETLI	ECHPT	SCPMU	HETLI	ECHPT	LEEFA	SCPMU	Yield (lb/A)
	(g ai/ha)	Prod./a		1st	2nd	7 DAT			14 DAT			7 DAT			14 DAT			9-Jul			18-Jul			7-Aug			21-Oct
Untreated[4]	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	4	2	3	26	2	8	28	1	2	4416
Clincher + Granite SC + COC fb. SuperWham + COC	280 + 35 + 2.5% v/v fb. 6726 + 2.5% v/v	13oz + 2oz + 2.5% v/v fb. 6qt + 2.5% v/v	2-3 lsr fb. 1-2 Til	22-Jun	10-Jul	0	0	0	0	0	0	0	0	1	0	0	0	53	29	83	100	94	90	100	81	100	8139
Clincher + COC fb. Ultra Stam 80 EDF + COC	315 + 2.5% v/v fb. 6726 + 2.5% v/v	15oz + 2.5% v/v fb. 7.4lb + 2.5% v/v	2-3 lsr fb. 1-2 Til	22-Jun	10-Jul	0	0	0	0	0	0	0	0	1	0	0	1	33	29	0	100	100	82	97	78	100	6954
Super Wham + Clincher + COC	4484 + 315 + 2.5% v/v	4qt + 15oz + 2.5% v/v	2-3 lsr	22-Jun	—	0	11	0	0	4	0	—	—	—	—	—	—	69	44	42	95	100	0	97	94	100	7373
Regiment + NIS fb. Super Wham + COC	30 + .125% v/v fb. 6726 + 1.25% v/v	0.54oz + 0.125% v/v fb. 6qt + 1.25% v/v	2-3 lsr fb. 1-2 Til	22-Jun	10-Jul	0	1	0	0	1	0	0	0	1	0	0	0	54	40	65	99	91	82	99	0	97	6836
Regiment + Abolish	30 + 3363	0.54oz + 1.5qt	2-3 lsr	22-Jun	—	0	0	0	0	2	0	—	—	—	—	—	—	55	49	67	99	47	61	100	22	31	7137
LSD (P=0.05)																											1113

[1] % Stand (percent stand reduction), % Stunting (percent stunting of rice), % Injury (percent injury to rice)

[2] 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)

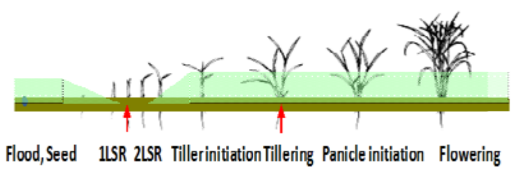
[3] PFS (pre-flood surface), PPI (pre-plant incorporated), fb. (followed by), lsr (leaf stage of rice), Til (tillers of rice).

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

Trial Information

1. Trial seeded June 7, 2012 with 120 lbs per acre of M206
2. Flooded to 3 inches June 7, 2012; drain start June 11; fully drained June 20, re-flooded June 25 to 4 inches
3. Watergrass was 2-3 leaf, bulrush was sprouted, ducksalad was 2-3 leaf, waterhyssop was 2 leaf on June 22.
   Watergrass was 2 tiller, ricefield bulrush was 1 tiller, ducksalad was tillering, waterhyssop was flowering, monochoria was 2 leaf on July 10.
4. Spray applications made with 20 gallons/acre using 8003 nozzles.
5. Weather conditions on June 22: Air temperature 68° F, water temperature 69° F, wind 6.5 MPH from the southeast.
   Weather conditions on July 10: Air temperature 72° F, water temperature 73o F, wind 2 MPH from the southeast.

Leathers Method



Application timing

Flood: June 7, 3" water depth

Begin lowering water: June 11

Water off plots: June 20

1st Application: June 22

Reflood: June 25, 4" water depth

Post permanent flood applications: July 10

Table 7. Leathers method for benzobicyclon .

Treatment	Rate (g ai/ha)	Rate Prod./a	Timing[3]	Date 1st	Phytotoxicity[1] 1st % Stand 7 DAT	% Stunting 7 DAT	% Injury 7 DAT	% Stand 14 DAT	% Stunting 14 DAT	% Injury 14 DAT	Weed Control[2] ECHPH 13-Jun	SCPMU 13-Jun	HETLI 13-Jun	ECHPH 12-Jul	SCPMU 12-Jul	HETLI 12-Jul	ECHPH 7-Aug	SCPMU 7-Aug	HETLI 7-Aug	Yield (lb/A) 21-Oct
Untreated[4]	–	–	–	–	–	–	–	–	–	–	3	6	5	22	4	14	28	3	1	4279
GWN-9796	250	57oz	DOS	8-Jun	NA	NA	NA	4	0	0	25	74	69	17	98	84	45	100	63	6701
GWN-9796 + Sandea	250 + 52.5	57oz + 1oz	DOS	8-Jun	NA	NA	NA	13	0	0	63	92	100	94	100	100	93	100	100	8661
GWN-10146	250 + 52.5	7.4 lb	DOS	8-Jun	NA	NA	NA	16	1	0	82	100	100	97	100	100	98	100	100	8958
GWN-9796	250	57oz	Post reflood	18-Jun	6	0	0	0	0	1	NA	NA	NA	0	92	89	0	100	38	4610
GWN-9796 + Sandea	250 + 52.5	57oz + 1oz	Post reflood	18-Jun	10	0	0	5	0	0	NA	NA	NA	95	100	99	96	100	100	7474
GWN-10146	250 + 52.5	7.4 lb	Post reflood	18-Jun	9	0	0	1	0	0	NA	NA	NA	73	98	93	81	100	88	7828
Cerano + GWN-10146	673 + 250	12lb + 7.4 lb	Post reflood	18-Jun	10	0	33	1	0	2	NA	NA	NA	96	100	99	93	100	88	8093
LSD (P=0.05)																				942

[1] % Stand (Percent stand reduction), % Stunting (Percent stunting of rice), % Injury (percent injury to rice)

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

[3] fb. (followed by), PFS (pre-flood surface), PWE (pre-weed emergence), lsr (leaf stage of rice), Til (tillers of rice).

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

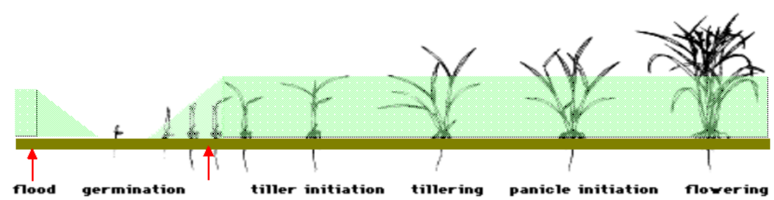
Trial Information

1. Trial seeded June 7, 2012 with 120 lbs per acre of M206
2. Flooded to 3 inches June 7, 2012; drain start June 11; fully drained June 13-14; re-flooded June 15 to 4 inches
3. No weeds visible on June 8.
   Watergrass was 1.5 leaf, ricefield bulrush and ducksalad are sprouted on June 18.
4. Liquid applications of GWN-9796 made with 10 foot boom with nozzles removed.
5. Weather conditions on June 8: Air temperature 71° F, water temperature 71° F, wind 2 MPH from the West.
   Weather conditions on June 18: Air temperature 71° F, water temperature 64° F, wind 3 MPH from the Southeast.
6. May 29, 2012 - 150lb ammonium sulfate = 30lb nitrogen

GWN-10146 is a granular formulation of benzobicyclon and halosulfuron. 7.4lb/a of product delivers 250g ai/ha benzobicyclon and 52.5g ai/ha halosulfuron.
GWN-9796 is a liquid suspension formulation consisting of 6% benzobicyclon
Sandea is a granular formulation of 75% halosulfuron.

All applications containing GWN-9796 were made with a 10ft spray boom with nozzles removes to simulate a direct stream application.
All granular formulations were hand dispersed across plot area.

Leathers method for benzobicyclon



Application timing

Day of seeding applications: June 7, 3" water depth

Begin lowering water: June 11

Water off plots: June 13 & 14

Re-flood: June 15, 4" water depth

Post permanent flood applications: June 15

Table 8. Drill seeded rice.

Treatment	Rate (g ai/ha)	Rate Prod./a	Timing[3]	Date 1st	Date 2nd	Phytotoxicity[1] 1st 7 DAT % Stunt	% Stand	% Injury	1st 14 DAT % Stunt	% Stand	% Injury	2nd 7 DAT % Stunt	% Stand	% Injury	2nd 14 DAT % Stunt	% Stand	% Injury	Weed Control[2] 9-Jul ECHPH	9-Jul CYPDI	18-Jul ECHPH	18-Jul LEFFA	7-Aug ECHPH	7-Aug ECHOR	7-Aug LEFFA	7-Aug ECHCG	Yield (lb/A) 21-Oct
Untreated[4]																		11	3	43	1	46	6	1	4	1420
Prowl H2O	1120	2pt	DPRE	11-Jun	—	0	4	0	0	0	0	—	—	—	—	—	—	76	31	77	75	57	29	73	73	5930
Prowl H2O fb. SuperWham + COC	1120 fb. 4480 + 1.25 % v/v	2pt fb. 4qt + 1.25% v/v	DPRE fb. 3-4 lsr	11-Jun	2-Jul	0	2	0	0	0	0	0	1	3	0	0	0	77	23	97	75	89	89	85	100	6949
Prowl H2O	1120	2pt	2-3 lsr (AFF)	22-Jun		0	0	0	0	0	0							0	32	18	0	29	0	32	30	2638
Prowl H2O + SuperWham + Clincher + COC	1120 + 4484 + 280 + 1.25 % v/v	2pt + 4qt + 13oz + 1.25% v/v	2-3 lsr (AFF)	22-Jun	—	6	0	1	4	0	0	—	—	—	—	—	—	81	71	97	100	97	99	42	100	7010
Clincher + COC fb. Superwham + COC	280 + 2.5% v/v fb. 4480 + 1.25% v/v	13oz + 2.5% v/v fb. 4qt + 1.25% v/v	2-3 lsr fb. 3-4 lsr (AFF)	22-Jun	2-Jul	1	0	0	0	0	0	1	0	2	0	0	0	83	6	97	88	100	100	64	100	7400
Granite SC + COC	35 + 2.5% v/v	2 oz + 2.5% v/v	2-3 lsr	22-Jun		0	0	0	0	0	0	—	—	—	—	—	—	75	57	95	6	100	100	0	100	7432
Granite SC + Prowl H2O + Clincher + COC	35 + 1120 + 315 + 2.5 % v/v	2 oz + 2pt + 15oz + 2.5% v/v	2-3 lsr	22-Jun	—	0	0	0	0	0	0	—	—	—	—	—	—	83	55	99	100	100	100	78	100	8275
Granite SC + Clincher + COC fb. SuperWham + COC	35 + 280 + 2.5% v/v fb. 6726 + 1.25 % v/v	2 oz + 13 oz + 2.5% v/v fb. 6qt + 1.25% v/v	2-3 lsr fb. PPF	22-Jun	10-Jul	0	0	1	0	0	0	0	0	1	1	0	0	78	52	99	100	100	100	43	100	8221
Abolish	3360	1.5qt	DPRE	11-Jun	—	0	0	0	0	0	0	—	—	—	—	—	—	40	48	33	38	27	0	91	45	2385
Abolish fb. SuperWham + COC	3360 fb. 6726 + 1.25 % v/v	1.5qt fb. 6qt + 1.25% v/v	DPRE fb. 3-4 lsr	11-Jun	29-Jun	0	0	0	0	0	0	1	4	2	0	0	0	24	18	93	63	90	90	70	100	6665
Abolish + SuperWham + COC	3360 + 6726 + 1.25 % v/v	1.5qt + 6qt + 1.25% v/v	3 lsr	29-Jun	—	1	4	3	1	0	0	—	—	—	—	—	—	0	0	98	0	95	100	0	100	7429
LSD (P=0.05)																										928

[1] % Stand (percent stand reduction), % Stunting (percent stunting of rice), % Injury (percent injury to rice)

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

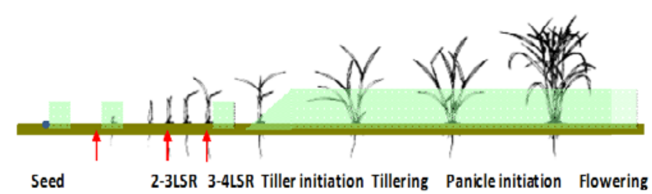
[3] fb. (followed by), lsr (leaf stage of rice), Til (tillers of rice), DPRE (pre emergent), EPE (early post emergent), AFF (after final flush), PPF (post permanent flood).

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

Trial Information

1. Trial seeded June 4, 2012 with 120 lbs per acre of M206
2. Flushed June 7, flushed June 13, flushed June 25; flooded July 3 to 4 inches
3. No weeds visible on June 11.
   Watergrass was 2-3 leaf, smallflower was sprouted on June 22.
   Watergrass was 4-5 leaf, and smallflower was 2 leaf on June 29
   Watergrass was 4-5 leaf, and smallflower was 3 leaf on July 2.
   Watergrass was 1 tiller, and sprangletop was 3 tiller on July 10.
4. Spray applications made with 20 gallons/acre using 8003 nozzles.
5. Weather conditions on June 11: Air temperature 69° F, wind 1.5 MPH from the southeast.
   Weather conditions on June 22: Air temperature 89° F, wind 5 MPH from the southeast.
   Weather conditions on June 29: Air temperature 66° F, wind 4 MPH from the south.
   Weather conditions on July 2: Air temperature 76° F, wind 3 MPH from the east.
   Weather conditions on July 10: Air temperature 72° F, water temperature 75° F, wind 2 MPH from the southeast.

Drill Seeded



Application timing

Pre-Emergent Application: June 11

Flushed: June 7, June 13, June 25

Applications: June 22, 29

Reflood: July 3, 4" water depth

Post-Permanent Flood Applications: July 10

Objective 3: To develop new alternatives to weed control through the exploration of agronomic and ecophysiological opportunities to minimize herbicide costs and environmental impacts with emphasis on alternative rice establishment methods for herbicide resistance management, including the development of a weed germination and emergence prediction approach for use in stale-seedbed systems.

3.1. Alternative stand establishment systems.

3.1.a. Introduction of new total herbicide options.

In our continuing effort to find alternative methods of establishment and alternative herbicide options we investigated the opportunity to use a couple herbicides in modified stale seedbed and drill seeded rice. In one trial, Goal (oxyfluorfen) and Sharpen (saflufenacil) were applied into the water in separate basins immediately following a shallow flood/flush (soil surface was just covered with water) of a stale seedbed method. The flood water was allowed to sub into the soil without drainage from the field. Flood water was returned 12 days later and soaked rice was seeded into the water one day after re-flood. Rice and weed stand counts were accessed for efficacy of herbicide on weeds and phytotoxicity of the herbicide on the rice crop. Untreated control counts were taken in an adjacent basin for comparison of efficacy. Figure 5 depicts weed control in these treatments. Both herbicides provided strong early control (11 days after application) of smallflower umbrellasedge and ducksalad (Table 9). Strong phytotoxicity was noted during early rice establishment (visual observation 10 days after seeding) in the Goal treated basin but not in the Sharpen treated basin. Later ratings (20 days after seeding) indicate partial watergrass control by herbicides (Table 10). Good control of smallflower umbrellasedge and ducksalad were maintained by both herbicides with Goal controlling these two weeds almost entirely. Bulrush germinated later and was partially controlled by Goal and only slightly by Sharpen. Goal is very phytotoxic to rice when utilized in this management system while initial indications are that Sharpen is not phytotoxic to rice (Table 10).

Figure 5. Early weed control by Goal and Sharpen when applied into flush water for stale seedbed.

Table 9. Early efficacy ratings (11 days after application) for Goal and Sharpen when applied to initial flush for stale seedbed.

	Mean number of plants per 20 1ft quadrats				
	Watergrass	**Bulrlush**	**Smallflower**	**ducksalad**	**waterhyssop**
Control	7	2	166	42	0
Goal	8	0	8	1	0
Control	10	0	121	73	1
Sharpen	8	0	14	0	1

Table 10. Late efficacy ratings (20 days after seeding) for Goal and Sharpen when applied to initial flush for stale seedbed.

	Mean number of plants per 20 1ft quadrats					
	Rice	**Watergrass**	**Bulrlush**	**Smallflower**	**ducksalad**	**waterhyssop**
Control	26	7	17	88	56	2
Goal	5	4	9	0	0	0
Sharpen	24	4	13	4	16	1

The drill-seeded trial entailed drilling alternating strips of three typical varieties of California rice (M-206, L-206, M-105). Water was flushed across the basin then allowed to drain. Goal and Sharpen were strip sprayed at right angle to the planting direction after rice had imbibed water for germination but prior to rice emergence through the soil. Untreated strips were incorporated into the spray pattern. Figure 6 depicts the weed control by these treatments. Plant stand and weed counts were conducted to determine treatment efficacy on weed species and phytotoxicity of the herbicides on the establishing rice. A slight crop height reduction was noted for Goal herbicide early (16 days after seeding) in the growing season (Table 11). Some early watergrass control by Goal was noted while significant broadleaf weed control was noted by both Goal and Sharpen (Table 11). Later season (33 days after seeding) weed control ratings indicate some watergrass, smallflower umbrellasedge and ducksalad control by both herbicides (Table 12). Bulrush apparently germinated later and therefore missed the application. With no competition from other weeds, sedges can often germinate in greater numbers than in control plots (Table 12).

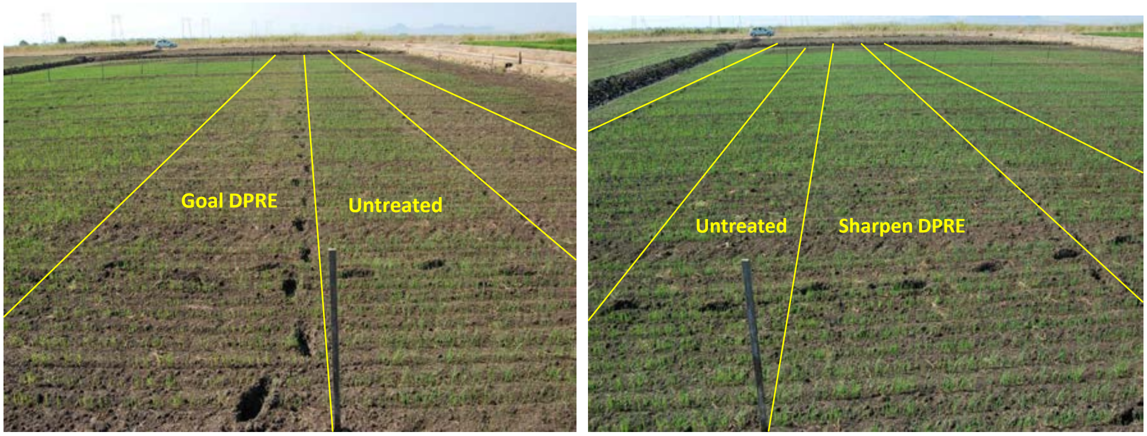


Figure 6. Early weed control by Goal and Sharpen when applied pre-emergent to drill seeded rice.

Table 11. Early evaluations (16 days after seeding) of rice growth and weed establishment in drill seeded rice.

		Mean plants per ft^2				
	Rice height	**Watergrass**	**Bulrlush**	**Smallflower**	**ducksalad**	**waterhyssop**
untreated	9.4	7	1	22	1	1
Goal	7.0	4	0	1	0	0
Sharpen	9.4	6	0	4	0	0

Table 12. Later evaluations (33 days after seeding) of weed establishment in drill seeded rice.

	Mean plants per ft^2				
	Watergrass	**Bulrlush**	**Smallflower**	**ducksalad**	**waterhyssop**
Untreated	10	15	12	10	0
Goal	5	32	4	3	3
Sharpen	4	2	3	2	1

Late season linier row stand counts indicate no significant stand reduction with either herbicide applied to drill seeded rice utilizing the method outlined above.

Table 13. Crop establishment in Goal and Sharpen treated drill seeded rice (33 days after seeding).

	Rice plants/meter row		
	M-202	**L-206**	**M-105**
Untreated	67	68	72
Goal	63	73	72
Sharpen	71	74	80

3.1.b. Prediction of weed emergence.
The lab at UC Davis has been working over the past few years to model the germination and emergence of two major species of weeds in the California rice cropping system. Both smallflower umbrellasedge (*Cyperus difformis*), and late watergrass (*Echinochloa phyllopogon*) have developed herbicide resistance. To better understand how to effectively time control for both resistant and susceptible biotypes, the members of the lab have begun to elucidate the mechanisms by which each species emerges, based on temperature and soil moisture.

Smallflower Umbrellasedge (*Cyperus difformis*)
Introduction
Smallflower umbrellasedge (*Cyperus difformis*) is a major weed of rice worldwide, with a short life cycle and massive seed production. It is considered one of the world's ten most important weeds, with a seedbank in Australia of 66,000 seeds/m^2; at the RES in Biggs, CA, there are an average of 4,874 seedlings/m^2, which is approximately 50 million/ha. In California, resistance to acetolactate synthase (ALS) inhibitors was reported in *C. difformis* populations of rice fields in 1993.

In California, due to increasing herbicide resistance, there is an urgent need for innovative, more efficient weed management tools. Knowledge of germination and emergence biology, and estimation of average times to these events, could improve smallflower management by allowing for better timing of: pre-plant (such as the stale seedbed method) and post-emergence control.

The objectives of these experiments were to: 1) Evaluate germination patterns of smallflower accessions resistant and susceptible to acetolactate synthase-inhibiting herbicides (ALS-R and -S, respectively) across varying temperature and moisture conditions; and 2) Validate a population-based threshold model capable of predicting emergence of smallflower in rice field.

Methods
To determine cardinal temperatures**,** germination tests were performed on July 2011 with 11-mo old seeds following a cold, wet stratification of 50 days. The photoperiod was similar to an early-spring day (14hrs light/10hrs dark). Three replications of 100 seeds in each dish per treatment (treatments were a range of temperatures from 13º–33.7º C) were set up in a gradient temperature table. The seeds were kept in aerobic conditions.

To determine Response to Osmotic Stress, solutions were prepared using Polyethylene Glycol 8000 (PEG), at water potentials (Ψ) of 0 MPa, -0.25 MPa, -0.45 MPa, and -0.65 MPa. The seeds were held at three constant-temperatures: 22º, 26.5º, and 29.8º C. Four replications of 100 seeds each were arranged in a split-plot design, at which temperature lanes constituted main plots. Each plot was then divided into three randomized subplots at which one dish per accession was placed. Experiments were conducted in a thermogradient table; germination was monitored four times a day throughout the first week, then twice a day until 15 days had elapsed.

To determine seedling emergence from rice soil containing ALS-R *C. Difformis*, two soils (HR and Rd) were placed in 1 sqft plastic nursery flats, and subjected to four irrigation regimes, starting May 2009: flooded, water saturated, daily watering, and 3-day flush, designed as randomized complete blocks (four replications per block). We counted emerged seedlings, and removed them at 2-3 day intervals. Data loggers recorded soil/air T and soil moisture every 15 minutes. The 2-leaf growth stage (approx. 2 cm in height) was considered an emerged seedling.

Results

Base temperature (T_b) values averaged 16.4° C ± 0.6. S plants require longer (+ 5.5 ºCd) thermal time ($\theta_{\mathbf{T(50)}}$) for germination than R plants. The R accession is able to germinate at dryer conditions than the S accessions (the median base water potential, $\Psi_b(50)$, is more negative). The different irrigation regimes affected the rates of weed emergence and these effects were presumably mostly on post germination growth than on germination (Figure 7).

In terms of application in the field, we can make projections for control timing. For early rice seeding (April 20th), smallflower reaches 2 leaf stage on 05/22 (i.e. accumulates 120º Cd); for May 5th rice seeding control should not be performed before 06/07 (Figure 8). Using the stale seedbed technique for rice mimic control causes earlier timing of post-emergence smallflower control compared to a conventional system; i.e. smallflower reaches 95% emergence 6-d earlier than in a non-stale seedbed system with a similar seeding date (May 7th).

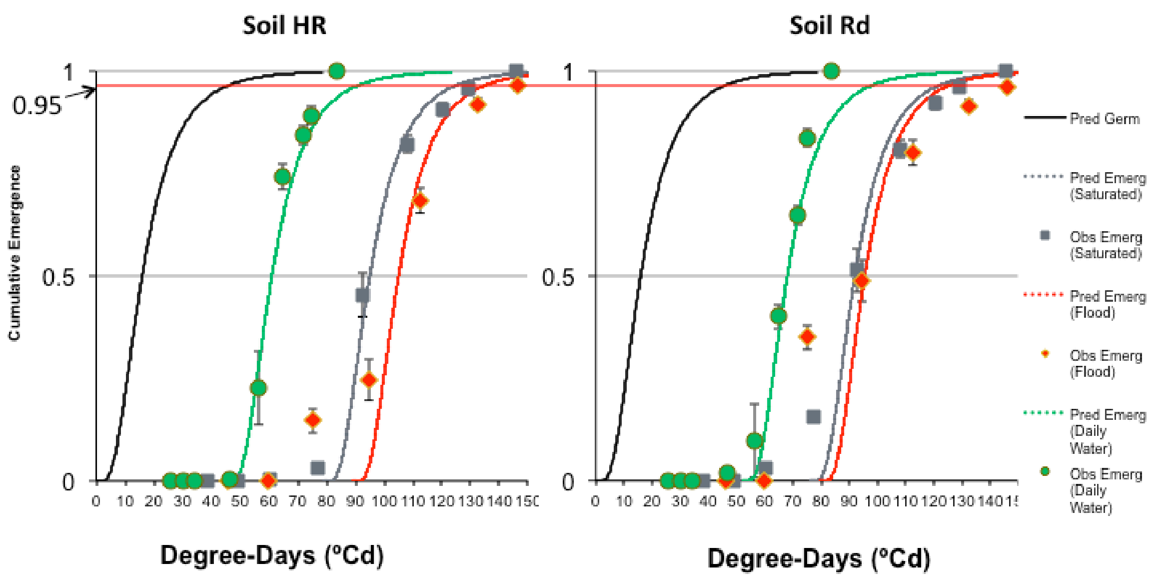


Figure 7. Cumulative observed emergence (symbols) expressed in growing degree-days for 3 water regimes in two soils, HR and Rd.

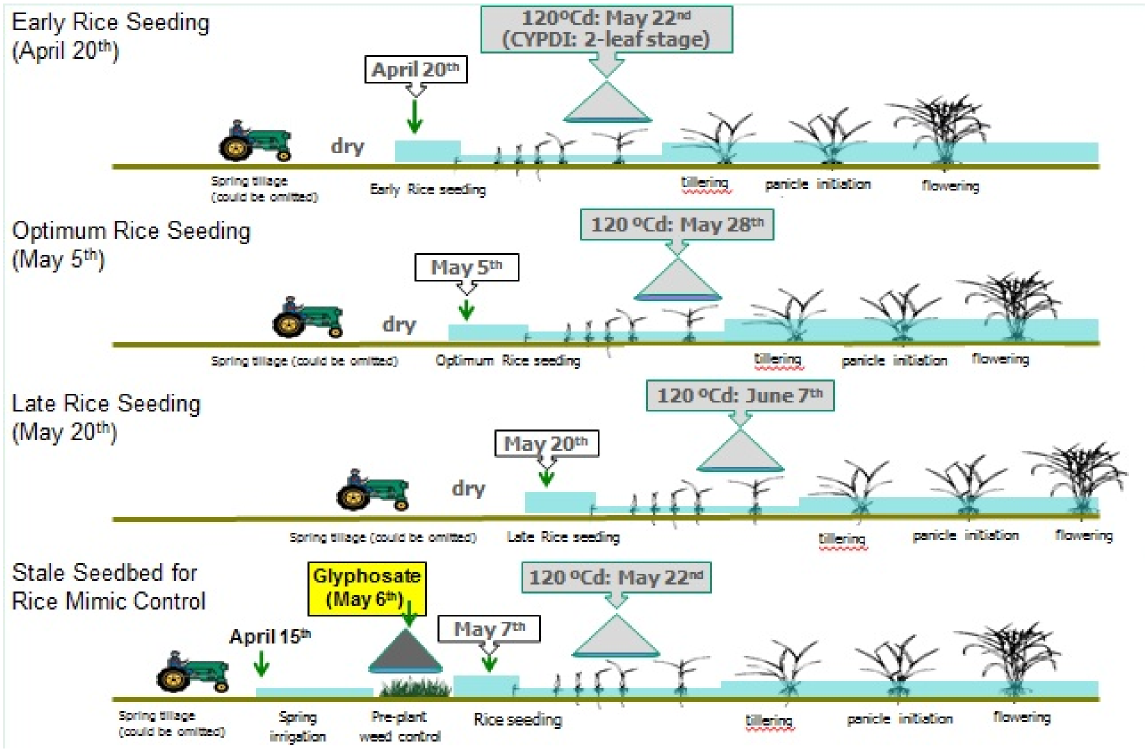


Figure 8. Based on the germination predictions, recommendations of application timings for control of resistant smallflower for Early, Optimum, Late and Stale Seedbed seedings of rice.

Late Watergrass (*Echinochloa phyllopogon*, a.k.a. "mimic")

Introduction

Herbicide-resistant late watergrass (*Echinochloa phyllopogon*, a.k.a. "mimic") is a major problem for California rice growers. The stale seedbed approach of recruiting and eliminating weeds prior to rice planting is a promising recourse. But in order for it to function, a grower needs to have accurate predictions of seed germination and seedling emergence. The speed at which these events take place depends on temperature, moisture and oxygen. We gathered germination data across a range of each of these factors and used a population based threshold model approach to estimate time to germination as determined by the temperature and the amount of moisture and oxygen in the soil. We then measured early growth rates and applied our models to seedling emergence in field soil. Aside from predicting emergence timing based on field temperature and moisture level, this approach was useful to identify the conditions necessary for optimizing seedling recruitment and reducing the time spent controlling weeds before planting.

No Stress

When seeds are kept fully moist but under aerobic conditions, germination is temperature-driven. We germinated seeds at 6 different temperatures and used the degree day model to determine that the base temperature for germination is 9.4 °C (49 °F) and that most germination is complete by about 50 thermal units (TU), calculated as:

$$TU = (T\text{-}T_b)t_g$$

T*b* is the base, or minimum, temperature required for germination to proceed; *T* is the ambient temperature and *tg* is chronological time.

Water Stress
When seeds are exposed to moderately dry conditions, germination is delayed but still occurs. We germinated seeds at 4 different water potentials (Ψ) to determine that the median minimum moisture level required for germination ($\Psi_b(50)$) is -1.06 MPa, about the same moisture level that is required by many non-aquatic species such as tomato. This explains why late watergrass can be problematic under a variety of stand establishment systems, regardless of flooding. Using a model similar to the TU model above, we can calculate the amount of moisture required for germination (θ_H) as 1.8 MPa day, a little under 2 days of full moisture:

$$\theta_H = [\Psi - \Psi_b(50)]t_g$$

Flood Stress
When seeds are exposed to anaerobic flooded conditions germination is unaffected. We germinated seeds at 5 distinct oxygen levels and found no affect on the speed or amount of germination. This explains why late watergrass can germinate both in flooded fields at extremely low oxygen levels or in well aerated soils.

Our Model
We determined the temperature and moisture conditions required for germination ($TU_{G(g)}$) by combining the thermal units and moisture time required by all fractions of the seed population. We then added our prediction for early seedling growth adapted to cover a range of seed burial depths (TU_{ShE}), and obtained a fairly accurate prediction of emergence from field soil (left) ($TU_{E(g)}$) based on our temperature and moisture data (Figure 9b).

$$TU_{E(g)} = TU_{G(g)} + TU_{ShE}$$

When we applied our model to emergence from field soil subjected to water stress (Figure 9), we see a discrepancy between predicted and observed emergence values. This can be attributed to slower post-germination growth rates, and may hint at a competitive disadvantage for late watergrass when grown under drier conditions.

When we apply the model to emergence from flooded soil (Figure 9), a discrepancy between predicted and observed emergence again occurs. This suggests that even though germination is not affected by anaerobic conditions, early growth is affected and slowed. Thus early growth is optimized under aerated soil.

Stale Seedbed
To reduce the time lag between the first irrigation of a field and application of herbicides (and subsequent rice planting), an accurate prediction of emergence timing is key. Based on the above information, to get full emergence prior to herbicide application, we suggest flooding fields for about 50 TU, and then drain them but keep them moist for about 110 TU.

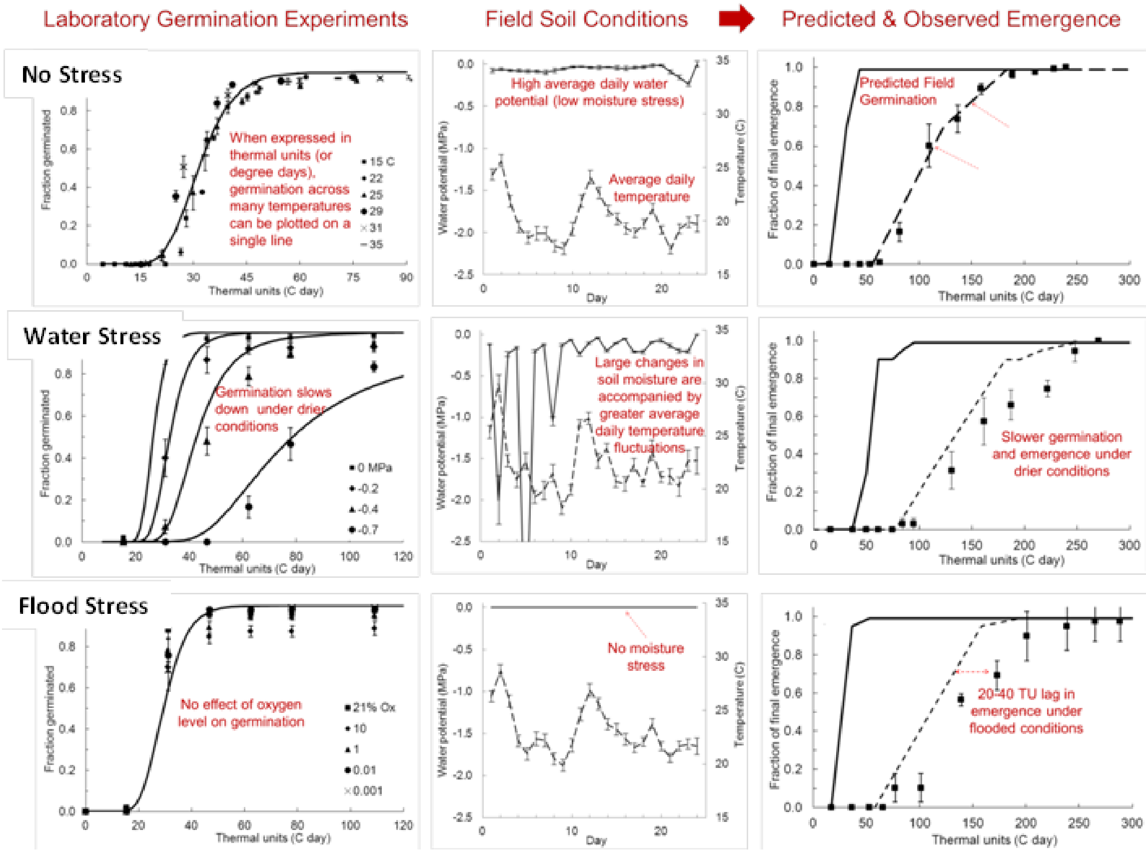


Figure 9. Dynamics of germination and emergence of late watergrass as affected by irrigation conditions and temperature accumulation over time.

Objective 4: Understanding herbicide resistance in weeds, providing effective diagnostic for use in weed management decisions, and test herbicide programs for resistance mitigation.

4.1. Diagnostic and detection of herbicide resistance

There has been growing concern by rice growers and pest control advisors (PCA's) that some smallflower umbrellasedge populations may have become resistant to the propanil formulations available to California rice growers. Populations of this weed have long been known to be resistant to several other common rice herbicides (ALS inhibitors), especially chemicals in the *sulfonylurea (SU)* class of herbicides. Herbicides in this class are: Londax (bensulfuron methyl), Sandea (halosulfuron-methyl), and Strada CA (orthosulfamuron); Granite SC or GR (penoxsulam) is also an ALS inhibitor for which resistant smallflower umbrellasedge biotypes can be found in CA rice fields. Resistance by a population of smallflower to one herbicide does not necessarily predict resistance to all other ALS inhibitors or sulfonylurea herbicides.

Procedure

We collected smallflower seed from eight grower fields where resistance was suspected. Seed was collected by gently bumping the seed head inside a bag; ensuring only mature seed would be collected. Seed samples were allowed to dry in the greenhouse for several weeks prior to testing. A known sulfonylurea susceptible line (Biotype 9) and known sulfonylurea resistant line (Biotype 10) were also included as controls. Three inch square pots were filled with rice soil from the Rice Experiment Station (RES). Finely ground soil was microwave sterilized then layered 1/4 "over the soil in the pots to ensure emerging seedlings were only those seeded and intended for testing. Pots were placed inside a large basin in the greenhouse and water was added up to for sub-irrigation. Smallflower seed was sprinkled on the moist soil surface. Water was held in the bench at 3 inches such that soil remained moist but not flooded. After establishment, plants were thinned down to 5 per pot. When plants were approximately at the 4-5 leaf stage of growth and average height was 6 inches, foliar spray applications were made.

Applications were made using a cabinet track sprayer with an 8001-EVS nozzle delivering 40 gallons of spray solution per acre. The herbicides tested were SuperWham! CA, Ultra Stam 80 EDF, and Riceshot 48 SF. Each herbicide was applied at 3, 6, and 12 lbai/a, which represents 1/2 field rate (0.5X), recommended field rate (1X) and twice field rate (2X), respectively; 0.125% crop oil concentrate was added to all treatments. An untreated control for each population was included. Each treatment was replicated four times. Seventeen days after application, live aboveground plant material was harvested per pot and weighed (g). Average weight of a treated pot was compared to the respective untreated control to determine the percent control by the individual treatment.

Results

The susceptible control population #9 averaged 47, 74 and 84% control across formulations for rates 0.5X, 1X and 2X, respectively, for an average control of 68% across all formulations and rates (Table 14). Out of the 10 populations tested, populations #6, #3, #4, and #8 were significantly resistant with average control across herbicides and rates ranging from 25% to 14%. Populations #1 and #10 were moderately resistant (% control of 52 and 42%, respectively).

There were differences in efficacy among the propanil formulations when weed control was averaged across rates and populations (Table 15). The herbicide Ultra Stam 80 EDF was 30% less efficacious than the other two propanil formulations. Figures below (10-16) illustrate experimental conditions and herbicide action results.

Conclusions and current work

Clearly, the repeated use of propanil has exerted selection for resistance among smallflower populations of CA rice fields. It is imperative to understand the mechanism of resistance in order to establish resistance mitigation programs. We are currently conducting research to help determine the mechanism(s) of resistance present in the resistant populations. We are also testing the efficacy of other available herbicides on the resistant populations in order to determine whether they are additionally resistant to these materials. Additional cultural methods may need to be implemented to help control these populations.

Table 14. Control of smallflower umbrellasedge populations with propanil; data (expressed as percent of the untreated control) are averages across three herbicides (Superwham! CA, Ultra Stam 80 EDF, and Riceshot 48 SF) and three rates (0.5X, 1X, and 2X; for X = 6 lb propanil/acre)

Population #	Weed Control

	-------(%)-------
9	68 A[1]
5	63 AB
7	61 AB
2	60 AB
1	53 B
10	42 C
6	25 D
3	19 D
4	18 D
8	14 D

[1.] *Values followed by the same letter are not statistically different according to Tukey's HSD; P = 0.05.*

Table 15. Control of smallflower umbrellasedge with three different propanil formulations (Superwham! CA, Ultra Stam 80 EDF, and Riceshot 48 SF). Data (expressed as percent of the untreated control) are averages across three herbicide rates (0.5X, 1X, and 2X; for X = 6 lb propanil/acre)

Propanil formulation	Weed Control
	-------(%)-------
Riceshot 48 SF	48 A[1]
Superwham! CA	46 A
Ultra Stam 80 EDF	33 B

[1.] *Values followed by the same letter are not statistically different according to Tukey's HSD; P = 0.05.*

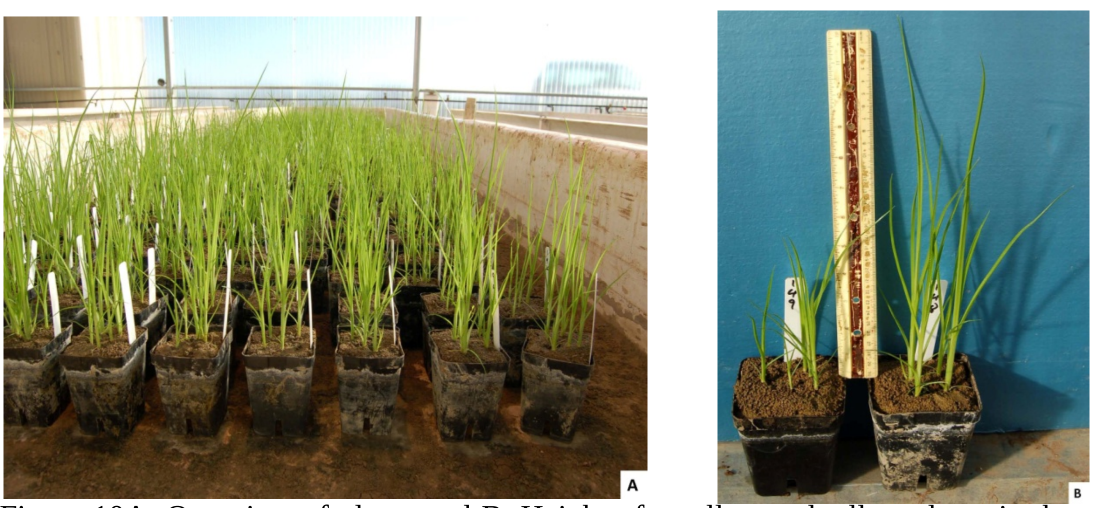


Figure 10A. Overview of plants and B. Height of smallest and tallest plants in the study at time of application.

Figure 11. View of plants ready for application in the cabinet track sprayer.

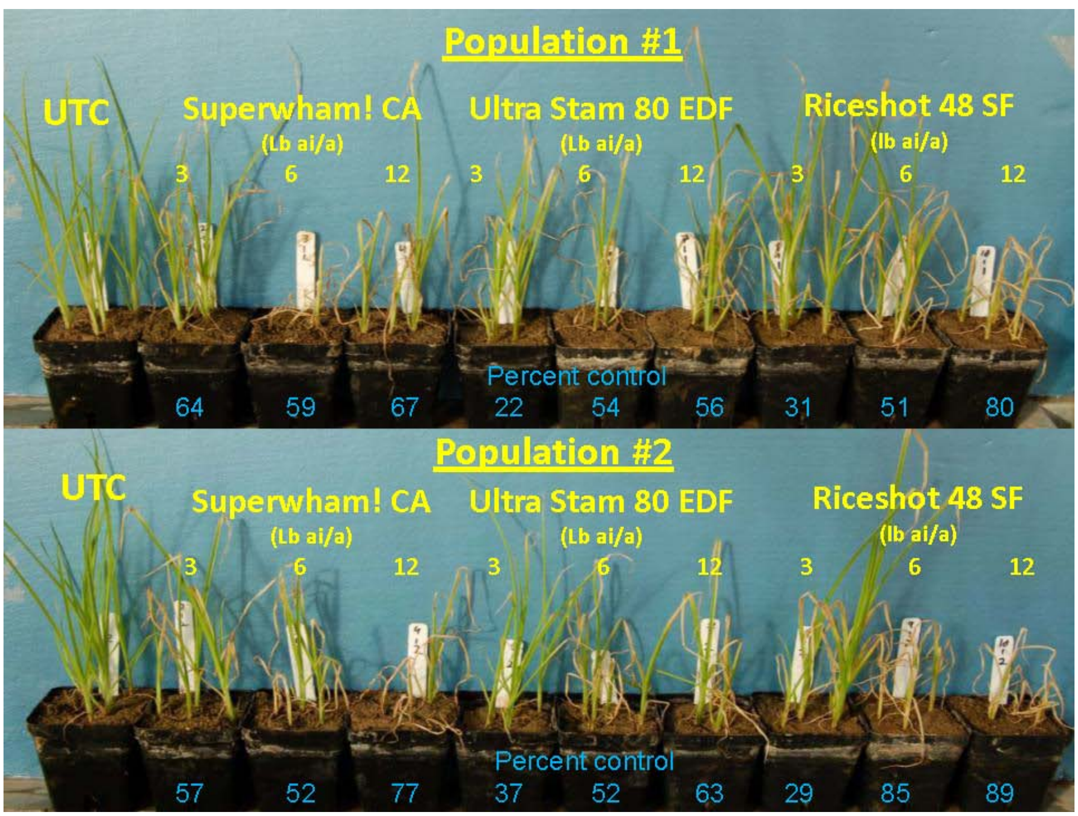


Figure 12. Smallflower umbrellasedge populations 1 and 2.

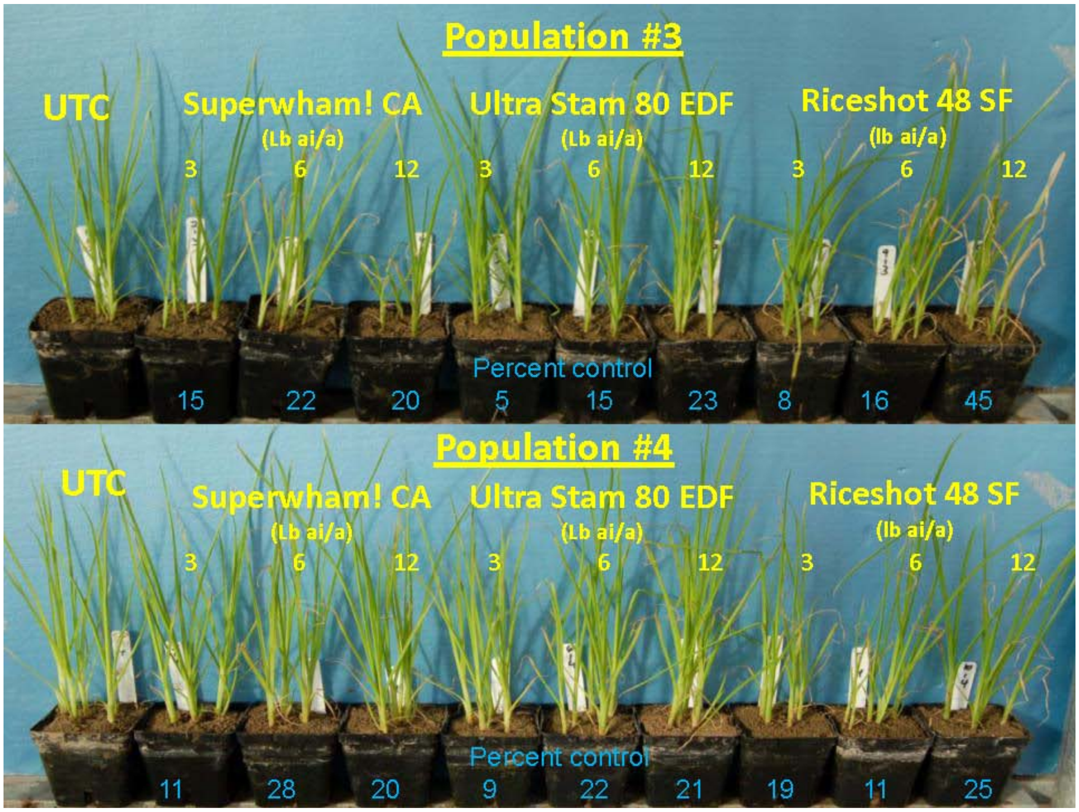


Figure 13. Smallflower umbrellasedge populations 3 and 4.

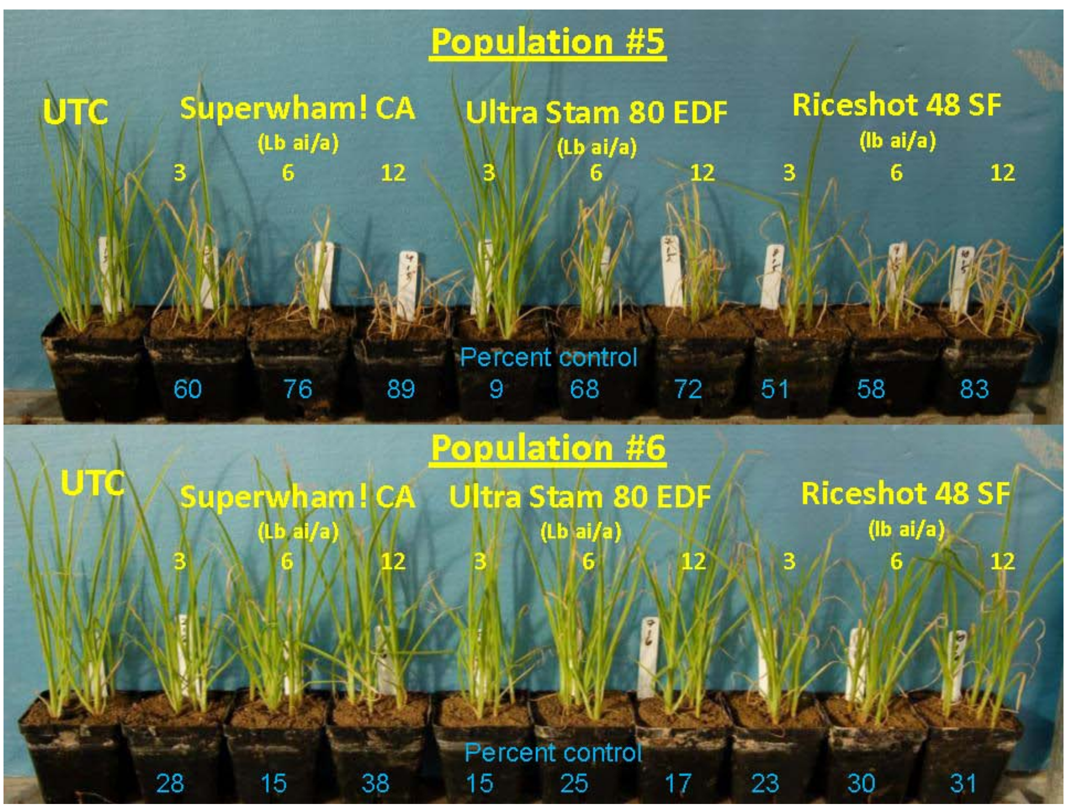


Figure 14. Smallflower umbrellasedge populations 5 and 6.

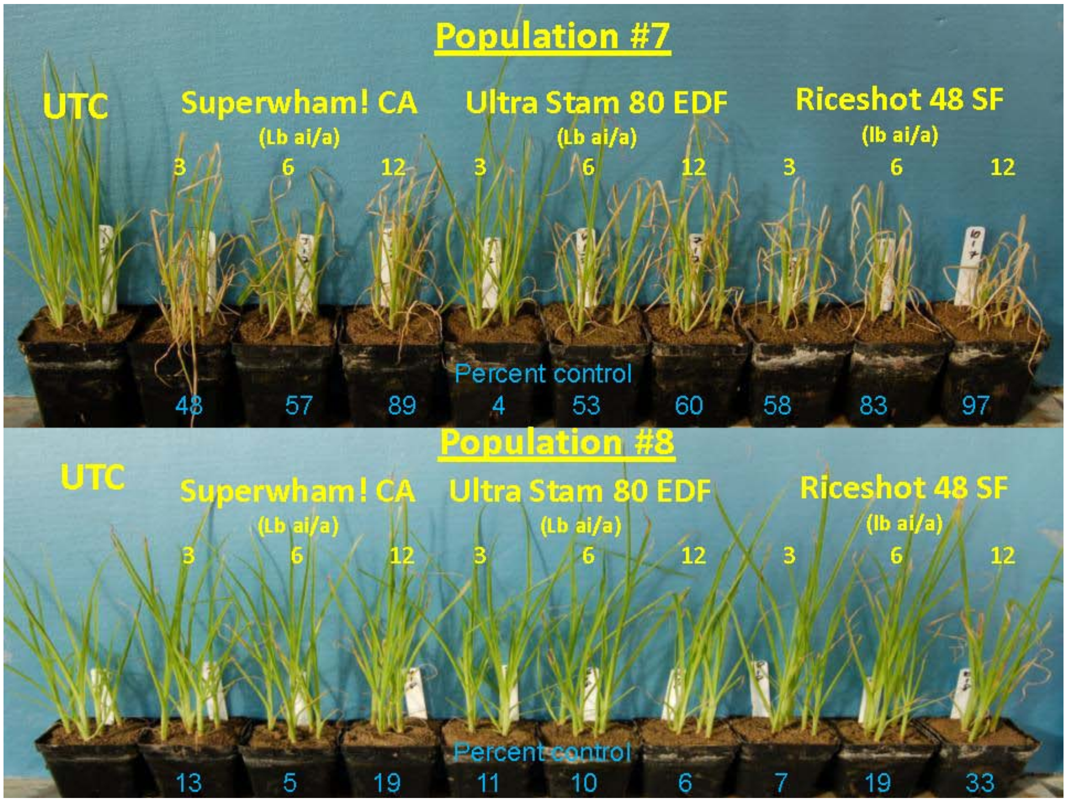


Figure 15. Smallflower umbrellasedge populations 7 and 8.

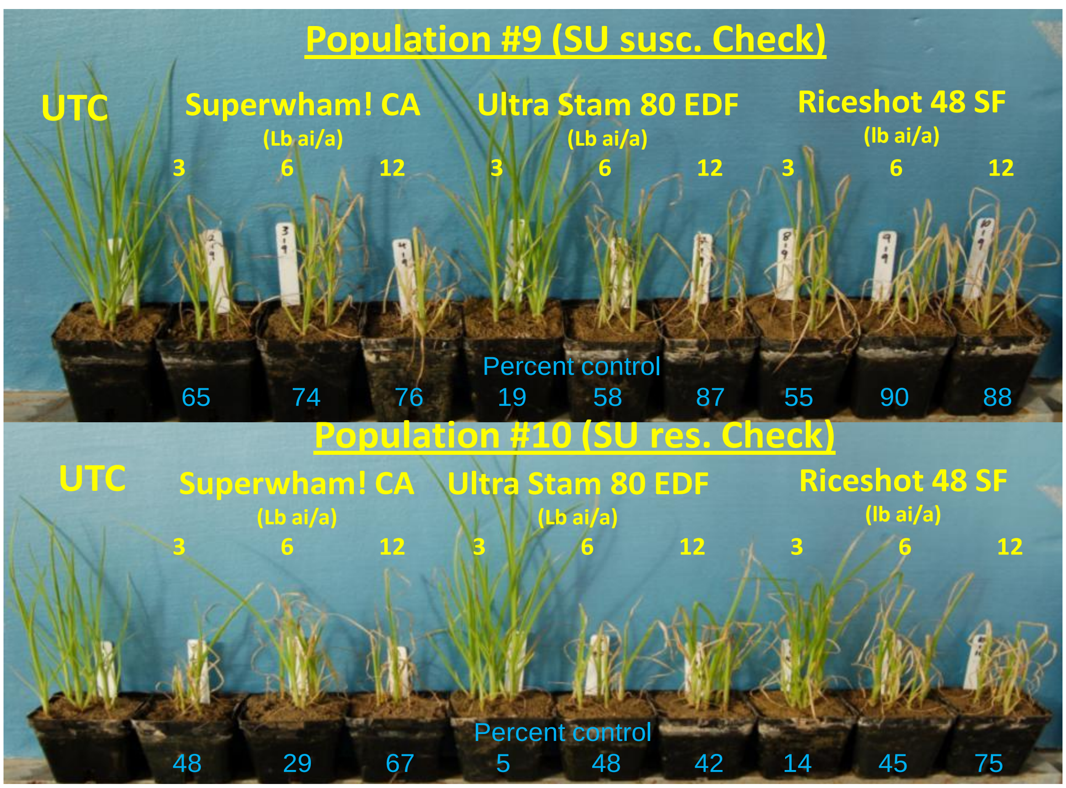


Figure 16. Sulfonylurea (SU) susceptible and resistant smallflower umbrellasedge checks.

A second trial was set up with the same herbicide applications being applied at an earlier stage of weed growth. Activity of the propanil formulations on younger plants is more striking. Separation of susceptible and resistant populations is clearer when treatments are applied at this earlier stage of growth. Populations 1 and 2 (Figure 17), 5 (Figure 19), 7 (Figure 20) and the sulfonylurea susceptible and resistant checks (Figure 21) are all susceptible to propanil at the early growth stage tested here. Populations 3 (Figure 18) and 8 (Figure 20) are moderately resistant, while populations 4 (Figure 18) and 6 (Figure 19) are quite resistant to propanil.

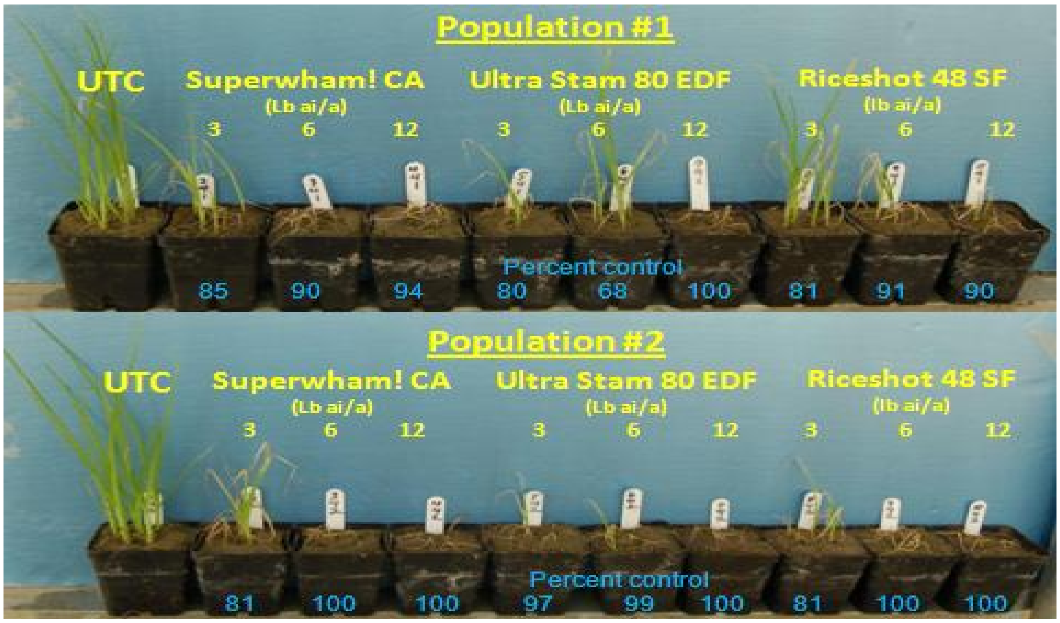


Figure 17. Smallflower umbrellasedge populations 1 and 2.

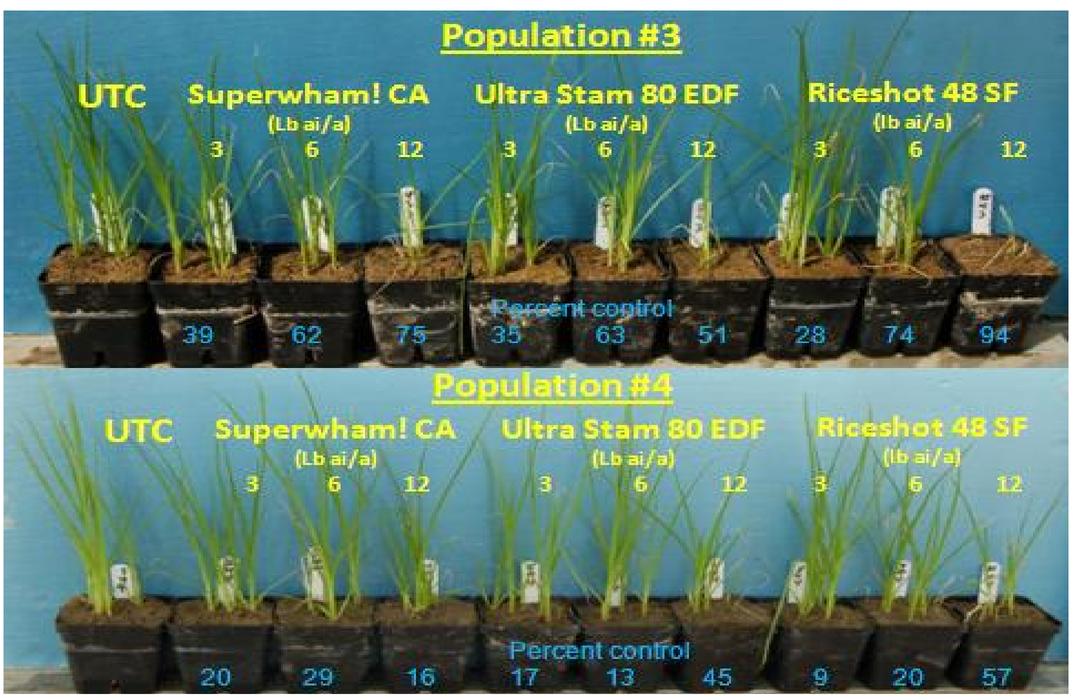


Figure 18. Smallflower umbrellasedge populations 3 and 4.

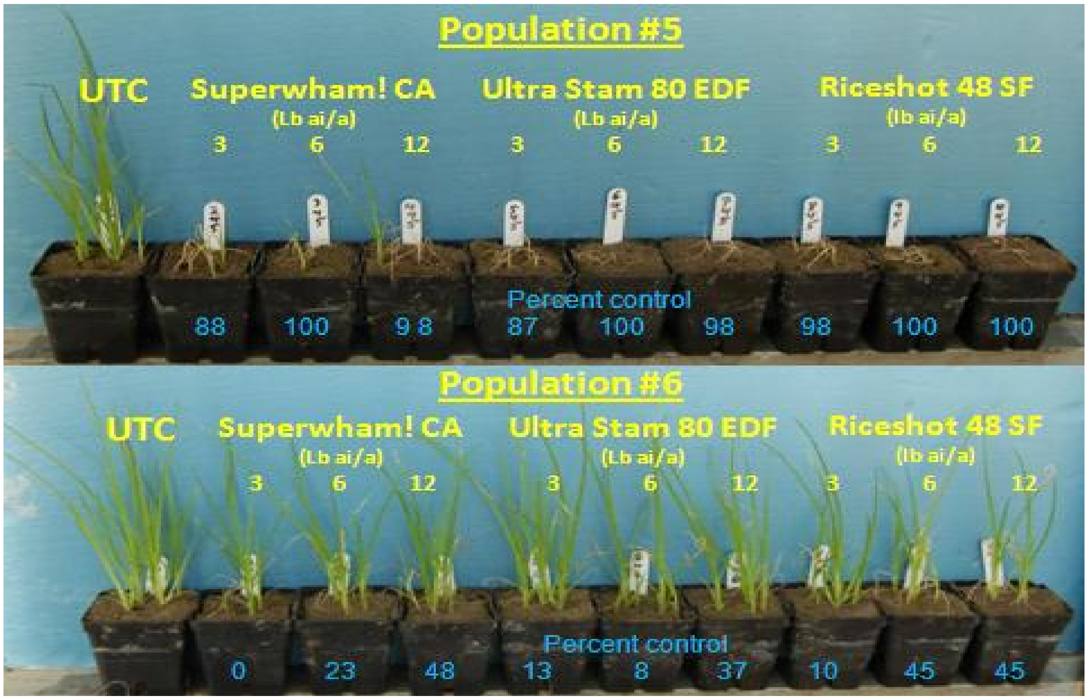


Figure 19. Smallflower umbrellasedge populations 5 and 6.

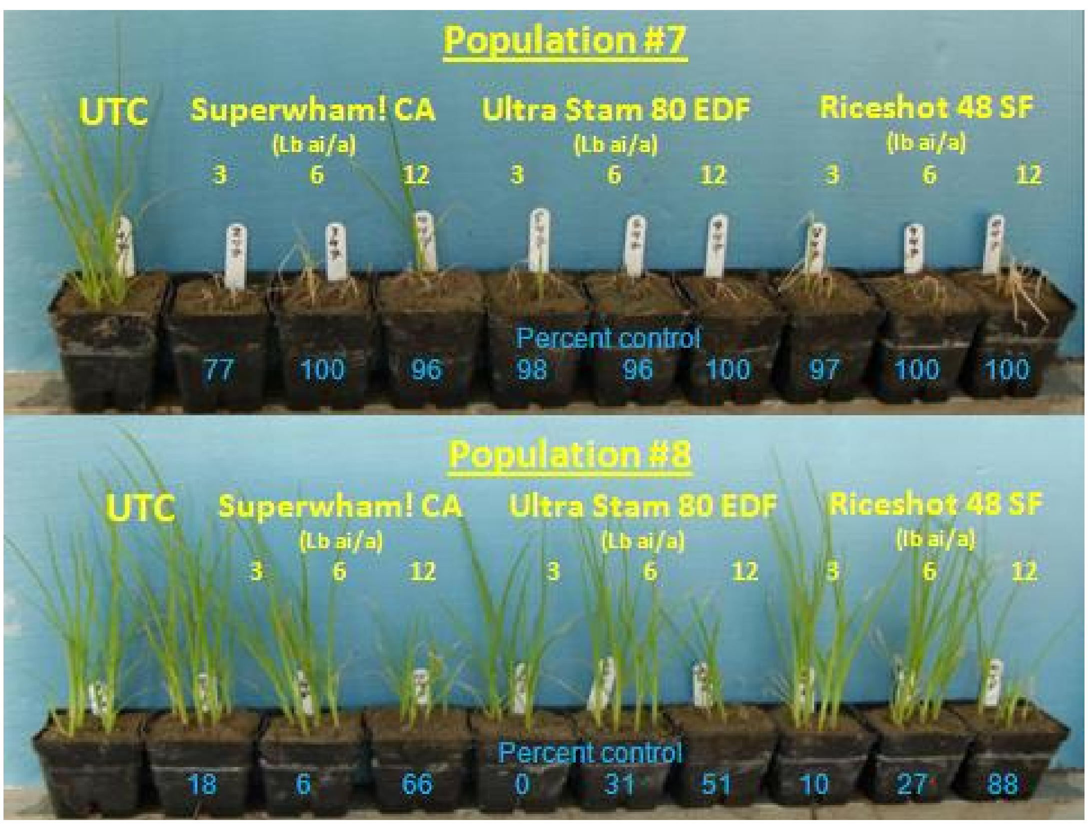


Figure 20. Smallflower umbrellasedge populations 7 and 8.

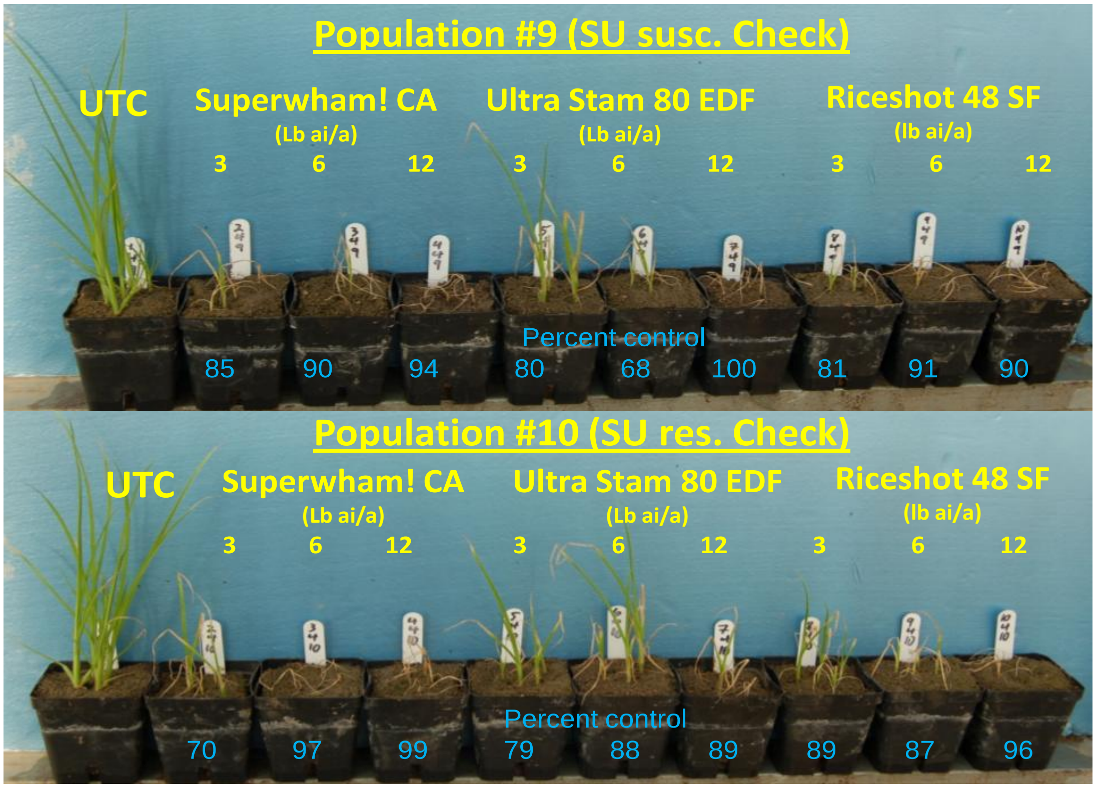


Figure 21. Sulfonylurea (SU) susceptible and resistant smallflower umbrellasedge checks.

Test of responses to other herbicides. Propanil resistant populations were then tested against a number of other foliar herbicides available to rice farmers in order to suggest programs for control in these fields. All herbicide treatments were made at recommended field rates. All propanil resistant populations are also resistant to Londax and exhibit some level of resistance to Granite SC and Sandea (Tables 22-24). It appears that there is no resistance to Shark H_2O at this time when Shark is applied as a foliar spray.

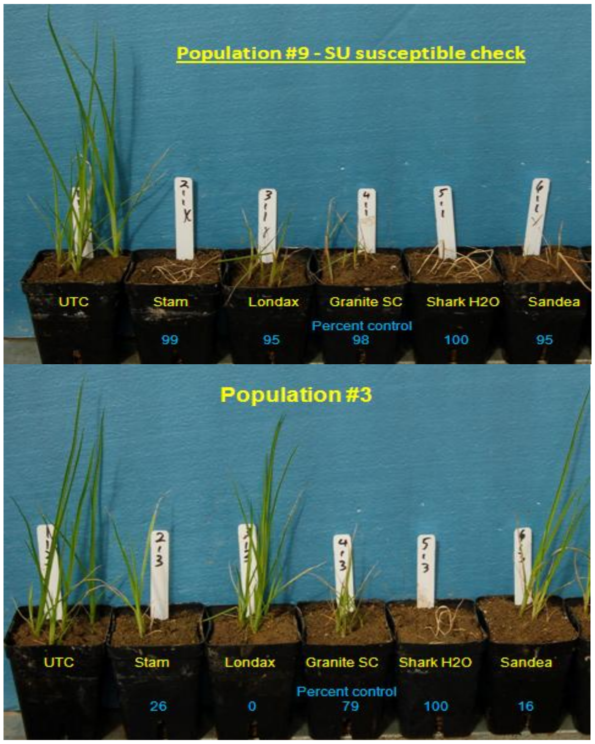


Figure 22. Sulfonylurea (SU) susceptible and population 3 resistant smallflower umbrellasedge tested against other sedge herbicides available for rice.

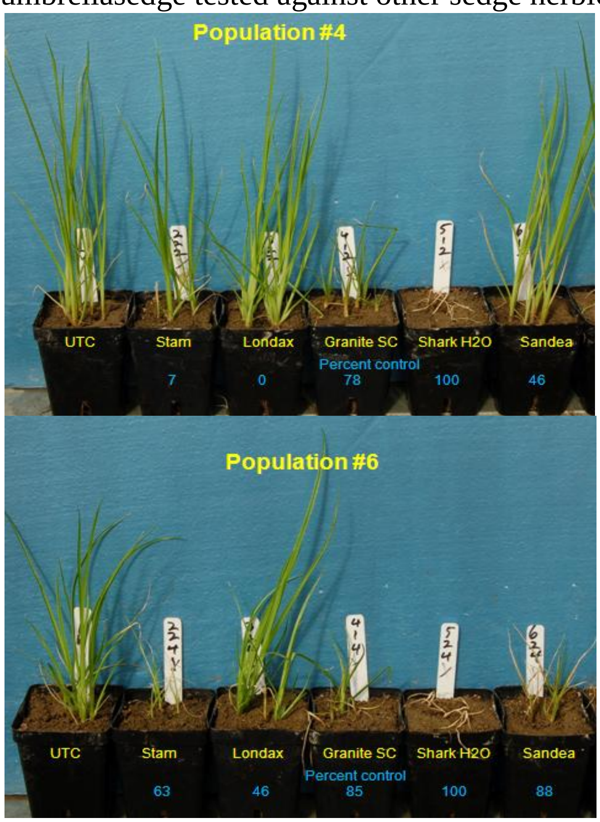


Figure 23. Populations 4 and 6 resistant smallflower umbrellasedge tested against other sedge herbicides available for rice.

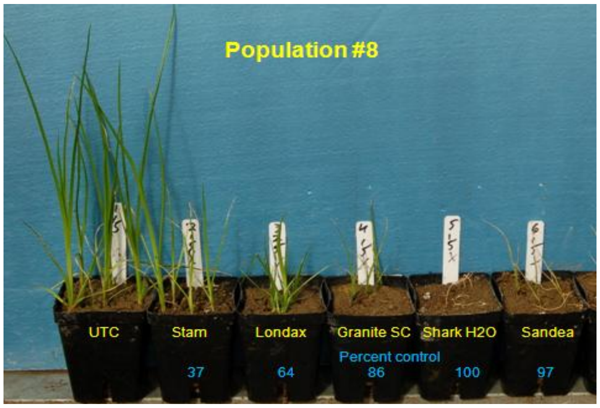


Figure 24. Population 8 resistant smallflower umbrellasedge tested against other sedge herbicides available for rice.

Ricefield bulrush resistance testing

Rice growers and pest control advisors (PCA's) have been noting reduced control of bulrush by propanil over recent years. Populations of this weed have long been known to be resistant to chemicals in the sulfonylurea (SU) class of herbicides. Herbicides in this class are: Londax (bensulfuron methyl), Regiment (bispyribac-sodium), Sandea (halosulfuron-methyl), Strada CA (orthosulfamuron). Efficacy testing was done on propanil, Londax, Granite SC, Shark H_2O and Sandea at recommended field rates.
Seed from eight potentially resistant bulrush populations were collected in 2011 for testing. Seed was collected by gently bumping the seed head inside a bag; ensuring only ripe seed would be collected. Seed samples were stored dry in the greenhouse for several weeks prior to testing. A known susceptible check line was also tested.

Bulrush seed was scarified with concentrated sulfuric acid soak for 2 minute then rinsed for 10 minutes in clear water. Seed was then soaked in water that was changed daily until seed germinated. Six germinated seeds were transplanted into three inch square pots that were mostly filled with common rice soil with a finely ground microwave sterilized soil layer on top. Pots were kept saturated, but not flooded. After establishment, plants were thinned down to 5 per pot. When plants were approximately 4 leaf and averaged 4 inches tall, foliar spray applications were made. Applications were made in a cabinet track sprayer using an 8001-EVS nozzle delivering 40 gallons of spray solution per acre.

Population #1 was presumed susceptible (Figure 25), but actually exhibits limited tolerance to propanil while fairly susceptible to the other herbicides tested. Population #2 also exhibits minor tolerance to propanil and Londax (Figure 25). Population #3 has resistance to Londax, propanil and to Sandea and Granite SC (Figure 26). (Granite is an ALS-inhibiting herbicide of the triazolopyrimidine-sulfonamide class). Population #4 also has resistance to Londax, moderate resistance to Sandea and propanil, but is susceptible to Granite SC (Figure 26). Population #5 exhibits moderate resistance to propanil (Figure 27). This population appears to be susceptible to the other herbicides tested. Population #6 has strong resistance to propanil and resistance to Londax, and Granite SC (Figure 27). Populations #7, 8 and 9 do not appear to have resistance to any of the herbicides tested (Figures 28 & 29). None of the populations of ricefield bulrush tested showed any resistance or tolerance to Shark H_2O applied as a foliar spray. Results of this testing suggest that two of the populations of bulrush seed were resistant to propanil. The remaining populations suspected of propanil resistance, but controlled in this experiment, were likely not controlled in the field due to some other mitigating factor associated with the application. Reasons for failure of propanil to control the weed include; but are not limited to poor coverage, weed shielded by canopy of rice, weather not conducive for efficacy, sub-optimal herbicide rate, improper tank mix, etc.

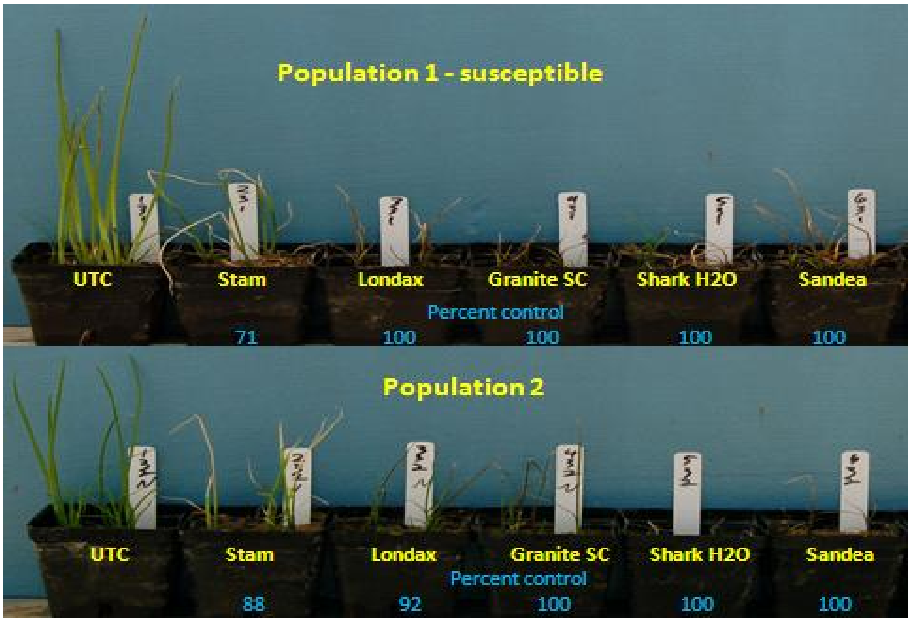


Figure 25. Ricefield bulrush population 1 (Susceptible check) and population 2.

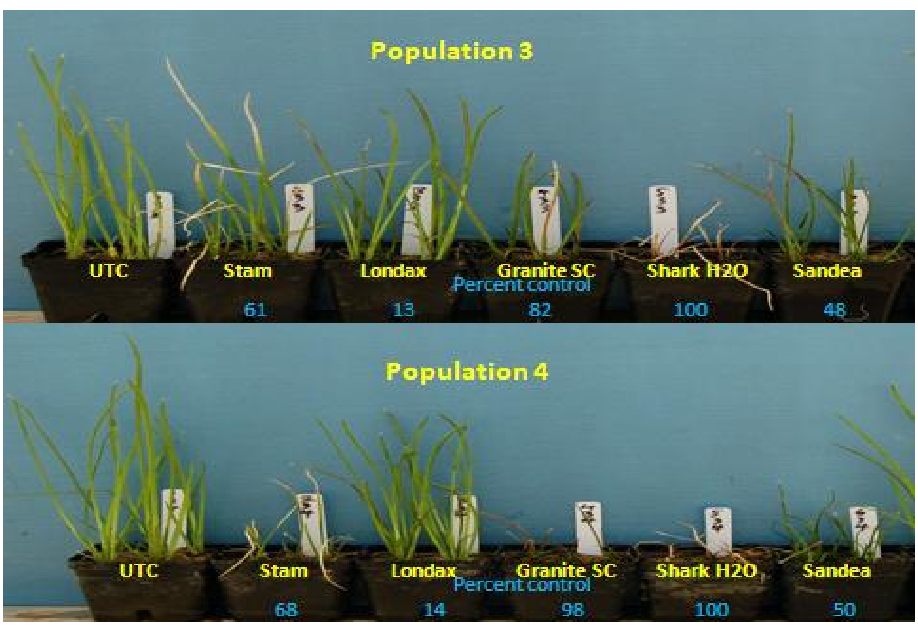


Figure 26. Ricefield bulrush population 3 and 4.

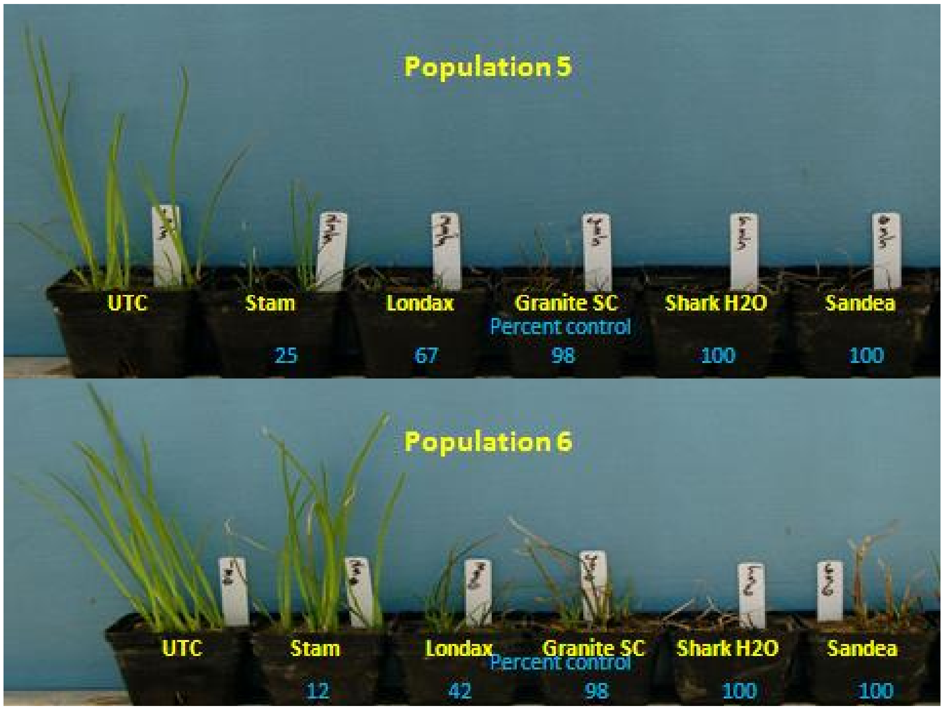


Figure 27. Ricefield bulrush population 5 and 6.

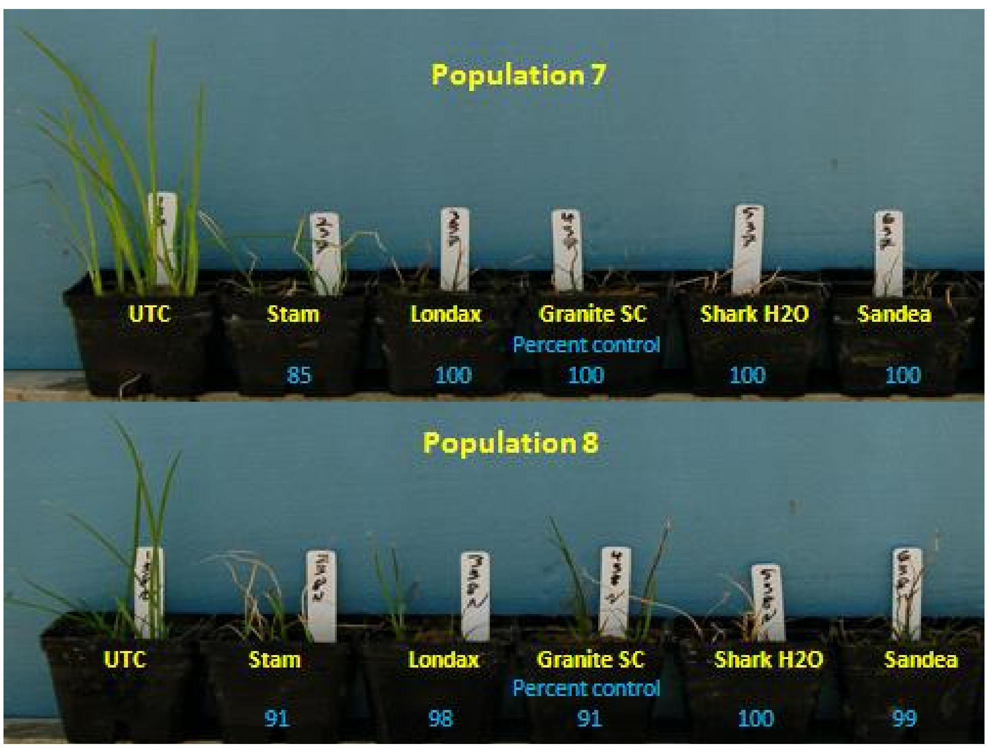


Figure 28. Ricefield bulrush population 7 and 8.

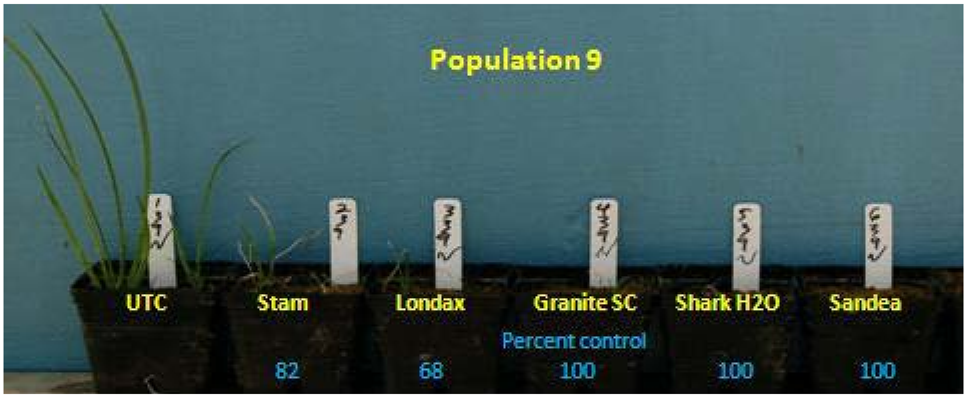


Figure 29. Ricefield bulrush population 9.

4.2. Field testing of herbicides

This year, we tested the new Valent V-10129 compound (10% thiobencarb + 0.46% imazosulfuron) , which will be commercialized as League MVP, at a cooperating farmer's field, who has been working with us for many years. The field has a population of multiple-herbicide-resistant late watergrass ("mimic"). The experiment was planted on May 22, with M-104, and the water level was maintained as a continuous flood with 3-4 inches of water. The field was drained a month before harvest.

The yields for this field were high (Table 16), ranging from 5750 lb/A (in the untreated controls) to 10462 lb/A. The V-10129 compound was most effective at a rate of 35 lb/A applied at the 2 leaf stage rice. Consistently with the resistance issue in this field the initial control of resistant late watergrass dropped a month after the first application in all treatments and was picked up by the applications of Regiment or SuperWham at the 1-2 tiller stage. The best long-term treatments were V-10129 (35 lb/A, 2 lsr) followed by SuperWham (6qt), Cerano followed by SuperWham and V-10129 followed by Regiment; these treatments also registered the highest yields. Rice field bulrush was consistently well controlled by V-10129 as was also ducksalad at the high rate. "Mimic" control in the Bolero Ultramax followed by Regiment treatment was short lived and dropped to 54% two months after seeding rice, which is consistent with the resistance to thiobencarb and bispyribac-sodium in this resistant biotype.

Table 16. Continuous flood trial at a resistant watergrass site.

Treatment	Rate (g ai/ha)	Rate Prod./a	Timing[3]	Application date 1st	Application date 2nd	% Stunting 14 DAT	% Stand 14 DAT	% Injury 14 DAT	2nd % Stunting 7 DAT	2nd % Stand 7 DAT	2nd % Injury 7 DAT	2nd % Stunting 14 DAT	2nd % Stand 14 DAT	2nd % Injury 14 DAT	Weed Control[2] ECHPH 13-Jun	SCPMU 13-Jun	HETLI 13-Jun	ECHPH 9-Jul	SCPMU 9-Jul	HETLI 9-Jul	ECHPH 23-Jul	SCPMU 23-Jul	Yield (lb/A)
Untreated[4]	—	—	—	—	—	—	—	—	—	—	—	—	—	—	5	5	4	18	3	2	53	12	5750
V-10219 fb. Regiment + UAN + NIS	3508 fb. 22.4 + 2.0% + 0.2% v/v	30lb (10% thiobencarb + 0.4% imazosulfuron) fb. 0.4oz + 2.0% + 0.2% v/v	2 lsr fb. 1-2 tiller	1-Jun	29-Jun	0	3	0	1	0	4	0	0	0	75	100	75	49	100	63	62	100	9713
V-10219 fb. Regiment + UAN + NIS	4092 fb. 22.4 + 2.0% + 0.2% v/v	35lb (10% thiobencarb + 0.4% imazosulfuron) fb. 0.4oz + 2.0% + 0.2% v/v	2 lsr fb. 1-2 tiller	1-Jun	29-Jun	0	9	0	0	0	0	0	0	0	89	100	70	42	100	92	73	100	10462
V-10219 fb. SuperWham + COC	4092 fb. 6726 + 1.25% v/v	35lb (10% thiobencarb + 0.4% imazosulfuron) fb. 6qt + 1.25% v/v	2 lsr fb. 1-2 tiller	1-Jun	29-Jun	0	0	0	0	0	0	0	0	0	47	98	91	42	100	92	83	100	10022
Cerano fb. SuperWham + Londax + COC	280 fb. 6726 + 67 + 1.25% v/v	5lb fb. 6qt + 1.6oz + 1.25% v/v	DOS fb. 1-2 tiller	22-May	29-Jun	—	—	—	0	0	0	0	0	0	71	60	30	49	38	25	93	100	9773
Bolero Ultramax fb. Regiment + UAN + NIS	3918 fb. 22.4 + 2.0% + 0.2% v/v	23.3lb fb. 0.4oz + 2.0% + 0.2% v/v	2 lsr fb. 1-2 tiller	1-Jun	29-Jun	0	3	0	0	1	6	0	1	0	89	73	85	49	50	100	54	100	8220
LSD (P=0.05)																							2987

Continuous Flood Resistant Watergrass Site

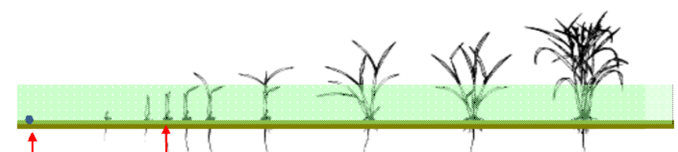
[1] % Stand (percent stand reduction), % Stunting (percent stunting of rice), % Injury (percent injury to rice)

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

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

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

[5] V-10219 consists of 10% thiobencarb + 0.46% imazosulfuron



Application timing

Flood: May 22, 3-4" water depth

Day of Seeding Application: May 22

Post-Flood Applications: June 1, 29

Trial Information

1. Trial seeded May 22, 2012 with 180 lbs per acre of M104
2. Trial managed as a permanent flood with flood water at 3-4 inches.
3. No weeds were visible when Cerano was applied on day of seeding May 22.
   Watergrass was 3 leaf, bulrush was 2 leaf on June 1.
   Watergrass was 2-3 tiller, ricefield bulrush was 3 tiller, arrowhead was 2 leaf, smallflower was 4", hyssop was flowering, and ducksalad was 3-4 leaf on June 29.
4. Spray applications made with 20 gallons/acre using 8003 nozzles.
5. Weather conditions on May 22: Air temperature 86° F.
   Weather conditions on June 1: Air temperature 91° F, wind 1 MPH from the south.
   Weather conditions on June 29: Air temperature 80° F, water temperature 89° F, wind 1 MPH from the south.

4.3. Mechanisms of resistance.

Over the past four years, graduate students in thelab at UC Davis have been working on elucidating the mechanism for glyphosate resistance in *Echinochloa colona* (junglerice). Junglerice, though not a current weed of rice, has the potential to move from field edges, where it is currently found, into rice fields. A suspected glyphosate-resistant (R) junglerice population was collected from a glyphosate-resistant cornfield near Durham in northern California where glyphosate had been applied at least twice a year for over six years. Based on the amount of glyphosate required to reduce growth by 50% (ED50), the R population was 6.6 times more resistant than the susceptible (S) standard population. Based on the glyphosate concentration that inhibits EPSPS by 50% based on shikimate accumulation (I50) in leaf discs, R plants were four times more resistant than S plants. By three days after treatment with 0.42 kg ae ha-1 glyphosate, the S population had accumulated approximately five times more shikimate than the R population. No differences in [14C]-glyphosate uptake and translocation were detected between R and S plants. However, partial sequencing of the EPSPS gene revealed a mutation in R plants causing a proline to serine change at EPSPS position 106 (P106S). Our results reveal the first case of a P106S target site mutation associated with glyphosate resistance in junglerice.

Objective 5: Investigations into new weed threats to California rice production.

5.1. *Ludwigia decurrens* (Winged primrose-willow) characteristics and rice herbicides that can control it.

***Ludwigia decurrens* (winged primrose willow) characteristics.**

Initial discovery of *Ludwigia decurrens* (Winged Primrose Willow) in Butte County was in August 2011. The Agricultural Commissioners and county extension agents determined the infestation covered several square miles generally south of Richvale. Most infestations are along borders of fields and irrigation canals. One field had an infestation throughout. It is likely that this weed has gone undetected for up to five years or more. *L. decurrens* can grow up to six feet or greater in height and produce many flowers (Figure 30A & B) and eventual seed capsules (Figure 30C). The stem of the plant is winged or star shaped in cross-section (Figure 30D). Seed capsules from this plant have thousands of seeds (Figure 30E), which are capable of floating on the water surface as a means of dispersal especially along irrigation canals. Indeed, the Butte County agricultural commissioner believes this has been the main means of dispersal across the majority of the infestation area.

Figure 30A. Winged primrose-willow plant in a field setting, B. flower, C. seed capsule, D. cross section of stem, E. dried seed capsule and seed.

Other potential means of spread are by seeds sticking to tillage equipment and seed remaining in combines between harvested fields. Additionally, it has been determined that plant fragments have the ability to grow roots within a day or two when in water (Figure 31A). This suggests that mowing of levees as a means of control may potentially increase dispersal of this weed. Testing in the greenhouse at the Rice Experiment Station indicates that the plant germinates best when the soil is moist but not flooded. However, the seed can germinate under water and eventually grow above the water surface with the potential to survive in a rice field and set seed. This plant also has the ability to form roots that grow upwards through the water column in order to scavenge oxygen near the water surface (Figure 31B).

Figure 31A. Piece of a winged primrose-willow plant growing roots after having been dropped into water, B. roots growing up from soil toward water surface.

Two contact herbicides were tested for early season control of *L. decurrens*. Both Goal and glyphosate caused strong leaf burn and it is unlikely the plants would survive in competition with other plants (Figure 32). Glyphosate will control older plants on levees, but any formed seed capsules will have viable seeds that will likely germinate the next season if not removed from the field and buried in a landfill as requested by the agricultural commissioner.

Figure 32. Efficacy of contact herbicides on young *L. decurrens* plants.

It is suggested that any levee spraying of known infestations should be done early in the season prior to the yellow flowers being visible. The majority of the seed dispersed from mature capsules will readily germinate under ideal conditions, however, there is evidence that a percentage of seed will germinate at a later timing. This is a survival mechanism by many plant species. Seed survival in soil has not been determined yet, although it is anticipated that buried seed will remain viable for several years until tillage moves it into a favorable germination zone. During harvest 2011 a sample of seed was collected from a return auger of a combine harvesting a field that had been hand rogued prior to harvest. The sample was largely smallflower umbrellasedge which is the same size as *L. decurrens* seed, but when seed was applied to wet soil at least one *L. decurrens* plant established. This suggests not only that hand rouging was not complete but also that a combine can easily spread *L. decurrens* seed to other fields. Plants that germinate and grow during the earlier part of the rice-growing season can reach 6 feet or more in height. Plants have been found germinating late in the season under favorable soil conditions and will flower when only 3 to 4 inches tall. It is anticipated that seed produced from these small plants would also be viable.

Rice herbicides to control winged primrose-willow. Testing of currently available rice herbicides indicates several potential options for control of this invasive weed within rice fields. We tested both early season water active herbicides (Cerano, Bolero Ultramax, Granite GR, Shark H_2O and Sandea). This was done at both early water flood and on larger, more established weeds. Application rates are presented in Table 17. 1. <u>The early flood treatment</u> entailed moistened soil for 3 days prior to flood being established. This was intended to simulate the flooding of large fields where the soil is moist as water is built up for flood. *L. decurrens* will germinate under these conditions prior to flood. Herbicide treatments were applied after flood was established and equivalent to day of seeding timing in a rice field. Early establishment in this case entailed plants allowed to establish to approximately 1.5 inches tall at time of application. 2. <u>The later timing</u> entailed plants that were allowed to establish and grow to approximately 2.5 inches in moist soil, then flood was established and herbicide treatments applied. This treatment method was intended to be similar to a drill-seeded situation where into water herbicides could be applied after establishment of permanent flood. We also tested later season foliar herbicides (Regiment, imazosulfuron, Granite SC, Sandea, Londax, Shark H2O, SuperWham, Grandstand, and Grandstand plus SuperWham) on both early establishment and larger more established plants. Application rates for foliar active herbicides are presented in Table 18.

<u>In continuous flood</u>, Cerano caused bleaching and eventual death of the small plants (Figure 33A). The later application of Cerano slowly bleached the plants and it is believed that they would not be able to produce viable seed (Figure 33B). Bolero Ultramax activity was fairly slow, but eventually killed both young and older plants when flood was maintained. Granite GR slowly bleached the young plants and it is expected to fully control the weed at that stage, however, more established plants survived the treatment and would likely set seed. Shark H_2O initially appeared to be very efficacious on both plant sizes, however plants were able to survive the treatment by putting on new leaves. These plants eventually flowered and would be expected to produce viable seed.

Sandea applied to the floodwater did not control the weed although it caused some malformations of the typical plant. It is likely the plants surviving Sandea would set seed (Figure 33B).

Table 17. Early season water active herbicides used in California rice.

Product	Active ingredient	Product rate
Cerano	clomazone	12lb/a
Bolero Ultramax	thiobencarb	23.3lb/a
Granite GR	penoxsulam	15lb/a
Shark H2O	carfentrazone	8oz/a
Sandea	halosulfuron	1oz/a

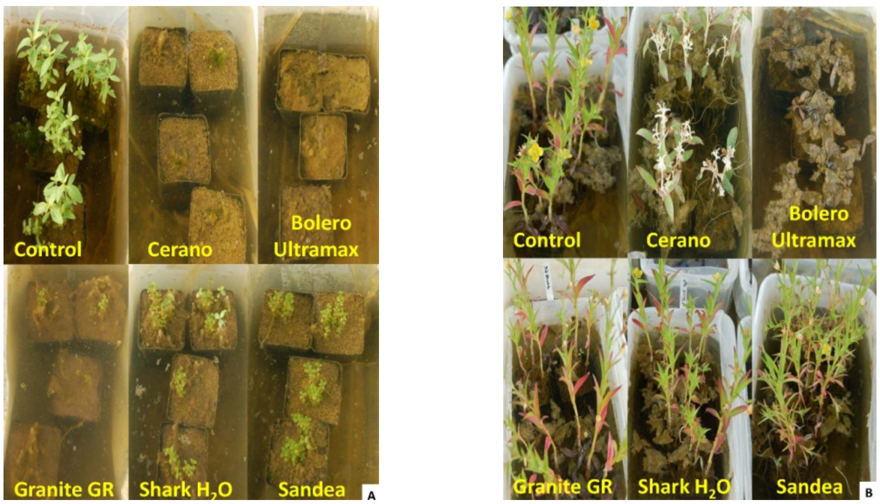


Figure 33A. Early flood application of water active herbicides. B. Application of water active herbicides after *L. decurrens* establishment.

In the foliar herbicide trial, Regiment did not control either young plants or older ones (Figures 34 and 35). Granite SC also did not fully control either age of plants. Sandea and Londax however appear to control the weed sufficiently when it is young but less effectively when it is more established. Shark H_2O initially appeared to be the best treatment with rapid severe burn of leaves, but the plants recovered by producing new leaves. These plants eventually produced flowers and would be expected to have viable seed. SuperWham provided some control when the plants were small, however the more established plants were not significantly hindered. Grandstand caused severe damage to both young and established plants. The tank mix of SuperWham and Grandstand was the most efficacious of all the foliar treatments.

Table 18. Foliar active herbicides used in California rice.

Product	Active ingredient	Product rate
Regiment	bispyribac-sodium	0.53oz/a
Imazosulfuron	imazosulfuron	6.4oz/a
Granite SC	penoxsulam	2oz/a
Sandea	halosulfuron	1oz/a

Londax	bensulfuronmethyl	1.7oz/a
Shark H2O	carfentrazone	8oz/a
SuperWham	propanil	6qt/a
Grandstand	triclopyr	1pt/a
SuperWham plus Grandstand	Propanil Plus triclopyr	6qt/a Plus 1oz/a

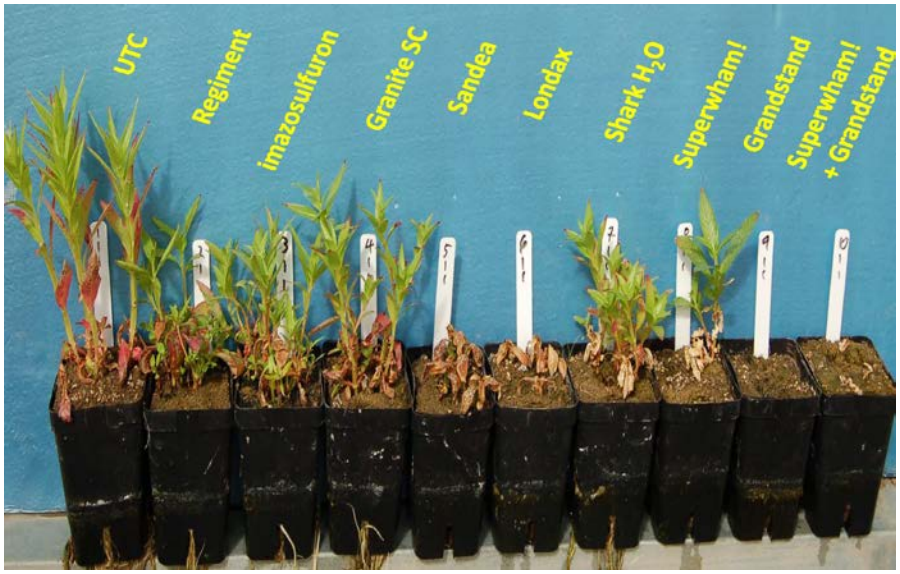


Figure 34. Early plant establishment of *L. decurrens* treated with foliar active herbicides.

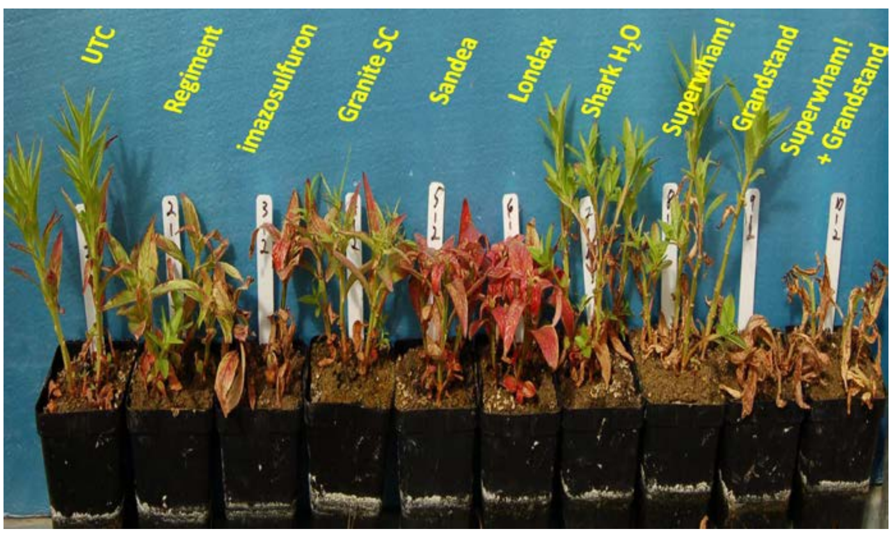


Figure 35. Late plant establishment of *L. decurrens* treated with foliar active herbicides.

Conclusion:

The best control strategy for *L. decurrens* in rice culture would be to use early water active herbicides like Bolero Ultramax, Cerano or Granite GR when the weed is very small and more vulnerable to treatment. If follow-up foliar herbicides are needed, early applications of Sandea or Londax may be sufficient when the weed is still very small.

Later foliar applications for control of *L. decurrens* would require Grandstand or a tank mix of Grandstand plus SuperWham. In all cases, the weed was growing without competition by other weeds or a rice crop. Some of the treatments that did not kill *L. decurrens* may have been sufficient to prevent establishment in an actively growing rice field and setting viable seed.

Means of restricting spread of this weed include cleaning tillage equipment and combines when leaving known infested fields or tilling and harvesting known infested fields last, to prevent seed spread.
A concerted effort by rice growers and the Butte County Agricultural Commissioners office to limit this noxious weed was implemented in 2011 and continued in 2012. Spraying of young plants on levees and irrigation ditches is continuing. Hand removal of seed producing plants with deposition of the plant material in the landfill has proceeded. With continuing diligence in restricting further seed production, this noxious weed can be contained to its current distribution and possible eradication over time.

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

Herbicide programs were conducted this year according to the main modalities of rice culture in California: Continuous flooded rice, partially flooded rice (pin-point and Leathers' method), and drill seeded rice. Two variants of the Leathers' method were implemented, one focuses on the use of foliarly-applied herbicides and the other involves an early re-flood when rice is at the 1.5 leaf stage of growth and weeds still small to enable the use of granular herbicide formulations to minimize drift problems. We will highlight here some of the newer compounds. In continuously flooded rice we tested again the new clomazone formulation Bombard. Efficacy on grasses and yields of were the same as for Cerano. We also tested a new active ingredient (benzobicyclon, formulated together with halosulfuron as a granule) that Gowan Company is pursuing for registration in California rice. Benzobicyclon is very effective on sedges, particularly ricefield bulrush, and many broadleaf weeds with some activity on grasses. The benzobicyclon + halosulfuron granule (Butte ®) provided good broad spectrum control enabling sequentials with Clincher, Cerano and Granite. Phytotoxicity was generally low, although there was some stunting observed in the combinations with Cerano. The Butte ® granule was also used with excellent results in a variant of the Leathers' method devised for use in conjunction with granular formulations, which involves initiating re-flooding when rice is ¼ inch pegged into the soil and achieving a water depth of 3 inches by the time rice is at the 1.5 lsr. Butte ® was applied at either DOS or immediately after re-flooding. A new cyhalofop (Clincher) formulation in granular form gave excellent watergrass control; excellent broad-spectrum control was achieved in sequence with Shark H_2O or Granite GR. A combination granule of thiobencarb + imazosulfuron (V-10219, League MVP ®) developed by Valent was used in continuously flooded rice at a site infested with herbicide-resistant late watergrass. The best long-term broad-spectrum treatments were V-10129 (35 lb/A, 2 lsr) followed by SuperWham, Cerano followed by SuperWham and V-10129 followed by Regiment; these treatments also registered the highest yields. V-10129 consistently controlled ricefield bulrush and ducksalad.

A new herbicide resistance situation resulted from the detection of propanil resistance in smallflower umbrellasedge and ricefield bulrush plants collected in grower's fields. In many cases propanil-resistant plants were also resistant to Londax, Sandea and Granite. Shark H_2O, applied as a foliar spray, controlled all the resistant smallflower umbrella sedge and ricefield bulrush plants. Because the resistant patterns involving other herbicides are variable, we strongly advise growers suspecting propanil resistance in these two species to submit seed samples for testing.

Winged primrose-willow (*Ludwigia decurrens*) is a quarantined invasive weed that was detected two years ago in irrigation canals and certain rice fields in Butte County. This weed has been evaluated for its characteristics and options for control. In greenhouse testing, Bolero Ultramax, Cerano or Granite GR were effective herbicides for use when the weed is very small (1-1.5 inch tall); also Londax and Sandea provided control at this stage. At later stages of plant growth, when the weed is >2.5 inches, foliar applications for control of *L. decurrens* would require Grandstand or a tank mix of Grandstand plus SuperWham. Sound recommendations to prevent seed spread of this weed would include: hand removal of seed producing plants with destruction of the plant material, cleaning tillage equipment and combines when leaving known infested fields or tilling and harvesting known infested fields last.

Testing of herbicides (new modes of action) for eventual use in stale seedbed techniques as alternatives to, or for mixtures and combination with, glyphosate and development of a model to predict smallflower umbrella sedge emergence in rice fields under different irrigation regimes were also part of this year's research. These are attempts for diversification of weed control techniques and for improving the timing and effectiveness of current weed control.

Our field and lab program seeks to assist California rice growers in their critical weed control issues of preventing and managing herbicide-resistant weeds, achieve economic and timely broad-spectrum control and comply with personal and environmental safety requirements.