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. To continue searching for and testing of 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. This includes the development of a weed germination and emergence prediction approach for the adequate Timing of Weed Control and also for use in stale-seedbed systems.

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), a farmer’s field in Glenn County (one site) and at a farmer’s field in Yuba County (one site). The two cooperating grower’s fields were infested with multiple-herbicide resistant late watergrass (“mimic”) and ALS-resistant sedges. This year, the Butte County sites were planted on May 22 and June 1, with M-205 and M-206, respectively. The site in Glenn County was planted May 15, 2014, with M-104. The Yuba County site was planted April 22, 2014, with M-206. 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, 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. Pinpoint 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 2.5 leaf stage of rice and re-flooded 48 hours after application (around the 4-5 leaf stage of rice). 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 CO₂-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 units of commercial product/acre and on Tables also as amounts of active ingredient (grams of active ingredient/hectare); 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 into-water treatments and best results were obtained when herbicide programs provided at least 95% of broad-spectrum weed control during the first month after seeding, thus enabling recovery of about 90% of potential yields. Figure 1 depicts the effects of competition by different weed infestation levels (expressed as % of the area covered by weeds or weed cover) on rice yields.
for seasons 2007 through 2014. Yields are expressed as percent of the best yields attained in this system each year. Weed cover in herbicide-treated plots is expressed in comparison to the percent weed cover in the untreated checks (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 percentage in Figure 1 (and in Figures 2 and 3) corresponds to the weedingness of 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 (3 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, herbicide-resistant escapes, and improve ease of harvest. In a continuously flooded system, after seeding into a flooded field, water depth is maintained at 4 inches throughout the season. When late post-emergence applications are needed, water is lowered to expose about 70% of weed foliage to the herbicide spray, but fields are never fully drained. This year four separate trials were conducted, one with combinations based on previously tested herbicide combinations, one testing benzobicyclon, one testing League MVP and one testing combinations appropriate for ALS- and propanil-resistant smallflower umbrella sedge sites.

In comparison to Figures 2 and 3, the regression in Figure 1 tends to have a lower slope of the line (less steep), which is due to 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 primarily aquatic weeds (Table 2) that do not compete very strongly with rice. Other highly 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 means that water-seeded and continuously flooded systems offer the best opportunities for choosing economic weed control programs. This year, watergrasses (primarily late), followed by ricefield bulrush, smallflower umbrella sedge, ducksalad, monochoria and waterhyssop were the predominant weeds. All weeds at our field site at RES are susceptible to herbicides, but we discuss and give herbicide options for fields with both herbicide-resistant and -susceptible populations. All herbicide options discussed are for weed control within 40 days after seeding (DAS), right after the critical period of weed control.

For control of multiple-resistant watergrass in locations with susceptible sedge and broadleaf populations, an application of a tank mixture of Abolish + Regiment (1.5qt/a + 0.53oz/a + 2.0% v/v UAN + 0.2% v/v NIS) at the 5 lsr (leaf stage of rice) provided good control within broad-spectrum programs (Table 2) at the Hamilton Road location in the Cooperative Rice Experiment Station (RES). Options for early sedge and susceptible grass control include Granite GR alone (15lb/a) at the 2-3 lsr, or Cerano (day of seeding at 12lb/a) followed by Granite GR (15lb/a) or GWN-10380 (7.5lb/a at 1 lsr) at the 2-3 lsr. GWN-10380 is a granular formulation of 3% benzobicyclon and 0.64% halosulfuron. All three options provide excellent control of ricefield bulrush, smallflower and ducksalad. The combination of Cerano followed by Granite provided the best watergrass (susceptible) control (100%). GWN-10380 is a good option for sites with ALS- and propanil-resistant sedge populations.

Bolero is a granular into-the-water herbicide that can be used to begin an herbicide program (Table 2). It controls sprangletop (although this weed should be uncommon in continuously flooded rice) and ALS-inhibitor and/or propanil-resistant smallflower umbrella sedge. A program with Bolero applied at 23 lb/a at 1 lsr (leaf-stage of rice) followed by Regiment (0.8oz/a at 3-4 lsr) provided good watergrass and ricefield bulrush control (93%) and excellent smallflower umbrella sedge control (100%). Regiment at the highest labeled rate is an option for fields with multiple-resistant watergrass. In susceptible watergrass fields, a good alternative is to follow Bolero with Granite SC + SuperWham (2oz/a + 6 qt/a + 1/25% v/v COC) at the 3-4 lsr. Watergrass control was good (92%), while ricefield bulrush, smallflower umbrella sedge and duckweed control were excellent (100%). When Bolero was followed by SuperWham alone (6 qt/a + 1/25% v/v COC) at the 3-4 lsr, control of ricefield bulrush was also good (96%), as was control of duckweed (92%).

An alternative granular formulation to control susceptible sedges and watergrass is Granite GR (15lb/a) at the 1 lsr, which can be followed by SuperWham (6 qt/a + 1/25% v/v COC) at the 3-4 lsr. It provided 100% control of sedges and ducksalad, and good grass control (96%).

Shark H₂O is a good herbicide for a program aimed at controlling ALS inhibitor- and/or propanil-resistant sedges (thus delaying the evolution of resistance to those herbicides). Shark H₂O alone into the water (7.5oz/a) at the 1 lsr had good early control of bulrush by 20 June (20 DAS) (86%) but late-emerging bulrush was not well controlled (Table 2). Smallflower umbrella sedge control was good and lasted until 40 days after seeding (86%). Abolish + Regiment (1.5qt/a + 0.53oz/a + 2.0% v/v UAN + 0.2% v/v NIS) at the 5 lsr provided 91% control of watergrass (this mixture is also good for the control of multiple-resistant watergrass). Regiment at the 5 lsr can also suppress resistant watergrass (although was not tested at a resistant watergrass site). When Cerano was applied day of seeding (DOS) (12lb/a) followed by Shark H2O and then by an Abolish+Regiment mixture, control of watergrass increased to 96%. When Granite GR (15lb/a) and Shark H₂O (7.5oz/a) were applied together at the 2.5 lsr, control of all weeds was excellent (100%).

To increase control of ricefield bulrush for sites with heavy populations, another option is to combine Shark H₂O + Halomax (7.5oz/a + 1.33oz/a) for in into-the-water treatment at the 2-4 lsr. Control of both ricefield bulrush and smallflower was excellent (100%) and the control of watergrass by Cerano (12lb/at DOS) was enhanced by this mixture. Any escapes can be controlled with a follow-up application of SuperWham at the 1-2 tiller stage (6qt/a + 1.25% v/v) (98% watergrass control).

In a second trial also at the Hamilton Road location in RES, we looked at herbicide combinations with Shark H₂O into-the-water (Table 3). Bolero and Cerano are two good options for early grass (watergrass and sprangletop) control in a Shark H₂O-based program. Bolero (23lb/a) applied at the 1 lsr had good watergrass control (95%), as well as good ricefield bulrush and smallflower control (80% and 96%, respectively). When Bolero was followed by Shark H₂O + Halomax (7.5oz/a + 1.33oz/a) at the 2-3 lsr, control of sedges increased to 98%. Cerano (10lb/a) at DOS alone controlled 92% of watergrass; when followed by Shark H₂O + Halomax (7.5oz/a + 1.33oz/a) at the 2-3 lsr, watergrass control increased to 99%. Sedge and broadleaf control was excellent (100%). Stand reduction was a problem in the Bolero-based treatments (Table 3).
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 is the area covered by weeds expressed as % of the untreated control plots; i.e. low relative weed cover corresponds to a high level of weed control); evaluations of weed infestation were conducted 40 days after seeding rice. Data are combined for the 2007 through 2014 continuously flooded experiments at the RES. “Early” and “Late” refer to applications made near the 3 leaf stage of rice and 1-3 tillers of rice, respectively.

The best yields in this continuously flooded system were achieved with Granite GR followed by SuperWham + COC (15lb fb. 6qt + 1.25% v/v) or Granite GR + Shark H2O followed by Abolish + Regiment +UAN+NIS (15lb + 7.5oz fb. 1.5 qts + 0.53oz + 2.0% + 0.2% v/v). Yields were 8160 lb/a and 8236 lb/a, respectively (Table 2).

1.2. Herbicide combinations for the Pinpoint systems
Often, cold weather or windy conditions in spring require early field drainage to favor rice establishment. Also, fields are often drained for use of foliar-acting early post-emergence herbicides. In this experiment weeds were controlled by foliar herbicide treatments applied during a period of field drainage for good weed exposure to the herbicides. The pinpoint system is a drainage system used when rice has already established (around the 3-4 leaf stage). Prevailing weeds in the pinpoint system were late watergrass, sprangletop, ricefield bulrush, and ducksalad (Table 4).

Weed infestations in our pinpoint plots have a stronger impact on yields (steeper slopes) 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 4) was managed by draining the water on June 10, approximately 10 days after seeding, when the rice was at the 2-3 leaf stage. It was re-flooded June 18 with rice just 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.
A tank mix of Clincher + Granite SC (13oz/a + 2oz/a + 2.5% v/v COC) at the 3-4 lsr has consistently provided good control of sedges and sprangletop. For sites with multiple-resistant watergrass, a follow-up of Abolish + Regiment (1.5qt/a + 0.53oz/a + 2.0% v/v UAN + 0.2% v/v NIS) or Regiment (0.8oz/a + 2% v/v UAN + 0.2% v/v) at the 1 tiller stage of rice should provide control of watergrass escapes. A 3-way tank mix of Clincher + Granite SC + Abolish (13oz/a + 2oz/a + 1.5qt/a + 2.5% v/v) showed comparatively reduced efficacy on the sedges (89% control of ricefield bulrush and 95% control of smallflower), and sprangletop (81%) by July 10 (40 DAS) (Table 4).

For sites with susceptible sedge and grass populations, there are several good programs. By July 10 (40 DAS) Regiment (0.67oz/a + 2% v/v UAN + 0.2% v/v NIS) at the 3-4 lsr followed by SuperWham + Clincher (6qt/a + 13oz/a + 2.5% v/v COC) at the 1 tiller stage of rice provided excellent broad-spectrum control. Clincher (13oz/a + 2.5% v/v COC) at the 3-4 lsr followed by SuperWham + Grandstand (6qt/a + 8oz/a + 1.25% v/v COC) provided excellent watergrass and sprangletop control (96% and 100%, respectively) and good ricefield bulrush and smallflower control (94% and 80%, respectively). Granite SC (2oz/a + 1.25% v/v COC) followed by SuperWham + Clincher (6qt/a + 13oz/a + 2.5% v/v COC) controlled watergrass (99%) and sprangletop (100%); efficacy on sedge and broadleaves was excellent (greater than 97%). As in previous years, a tank mixture of Clincher and SuperWham (13oz/a + 6 qt 2.5% v/v COC) at the 3-4 lsr provided good broad-spectrum control of all weeds except for broadleaves, but the antagonism between the two herbicides lowered their efficacy slightly (control of sprangletop was only 75%) (Table 4).

Yields were generally high in the pinpoint system this year (Table 4). Highest yields in this system were the Clincher + Granite SC + COC fb. Abolish + Regiment + UAN + NIS (13oz + 2oz + 2.5%v/v fb. 1.5 qts + 0.53oz + 2.0% + 0.2% v/v), Clincher + Granite SC + COC fb. Regiment + UAN + NIS (13oz + 2oz + 2.5%v/v fb. 0.8oz + 2.0% + 0.2% v/v) and the three-way tank mix of Clincher SC + Granite SC + Abolish + COC (13 oz/a + 2 oz/a + 1.5 qt/a + 2.5% v/v at the 3-4 lsr). Yields were 8766 lb/a, 8750 lb/a and 8734 lb/a, respectively.

A second pinpoint trial at the Hamilton Road location in RES, incorporating foliar applications of Shark H2O (Table 5) was drained at the same time as the first pinpoint flood, but was reflooded earlier (June 15). This may be a good option for site with propanil and ALS-resistant smallflower umbrella sedge. Cerano (12 lb/a) applied day of seeding, followed by an early foliar application of Shark H2O (7.5 oz/a) (2-4 lsr) followed by SuperWham+ COC (6 qt/a + 1.25% v/v) at the 1-2 tiller stage provided the best overall weed control, with 94% of late watergrass, 97% control of ricefield bulrush, and 100% control of smallflower (July 10, 40 DAS) (Table 5). The same treatment followed by a second foliar application of Shark H2O at the 1-2 tiller stage also had excellent control of sedges, but less control of late watergrass (only 84%); however, we strongly discourage sequential applications of herbicides with the same mode of action to avoid the evolution of resistance to this herbicide in weeds.

The best yield in this trial was the treatment of Cerano fb. Shark H2O fb. SuperWham +COC (12 lb fb. 7.5oz fb. 6 qt + 1.25 %v/v) which had a yield of 7329 lb/a.
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, as are barnyardgrass and smallflower umbrella sedge) and is less favorable for aquatic species (ricefield bulrush, ducksalad, and redstem). Thus dry seeding is useful for alternation with water-seeded systems when the pressure of aquatic weeds becomes problematic. Main weeds in the experiment were the *Echinochloa* complex, sprangletop, and some smallflower umbrella sedge. Before heading, individual species within the *Echinochloa* complex are difficult to differentiate. Later weed ratings (60 DAS) show the infestation and control percentages for individual species.

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.

Prowl is a pre-emergence herbicide that can protect from weed emergence after seeding rice during the period prior to the permanent flood. It controls watergrass, barnyardgrass, and sprangletop and has some activity on smallflower umbrella sedge. Other good sprangletop herbicides for this system are Abolish, and Clincher. Main weeds in the experiment were the *Echinochloa* complex and sprangletop (Table 6).

For early weed control, some herbicides are applied before rice emergence. For a delayed pre-emergence application, the field is first drill seeded into dry soil. The field is flushed once, to moisten the soil and imbibe the rice seed to initiate germination and emergence, and then a
herbicide can be sprayed onto a moist soil surface: this is termed delayed pre-emergence (DPRE) application. Prowl (2 pt/a) is a pre-emergence herbicide that can protect from weed emergence after seeding rice during the period prior to the permanent flood. Abolish is another option as a pre-emergence herbicide. Both herbicides should be active against watergrass, barnyardgrass, and sprangletop; Abolish is more active on smallflower umbrella sedge than Prowl. Prowl H2O (2pt/a) applied alone at delayed pre-emergence (DPRE) provided only partial (34%) Echinochloa suppression, 75% control of sprangletop and 85% smallflower umbrella sedge control, indicating Prowl is not a stand-alone herbicide but that it can be a useful mixing partner to limit weed emergence from soils (does not have foliar activity). Abolish (1.5 qt/a) provided poor late watergrass control (only 5%) but better early watergrass/barnyardgrass control (up to 76%) and controlled sprangletop by 70%. Abolish alone in DPRE controlled smallflower umbrella sedge by 93% (Table 6). A follow-up application of a tank mixture of Abolish and Regiment (Treatment 5, Table 6) (1.5qt/a + 0.53oz/a + 2.0% v/v UAN + 0.2% v/v NIS) provided excellent watergrass control (97% of late watergrass at 40 DAS).

The tank mixture of Prowl H2O (2pt/a), SuperWham (4qt/a) and Clincher (13oz/a) applied with 2.5% COC at the 2-3 lsr is a standard mixture that controlled emerged grasses (94% control of late watergrass, 61% control of sprangletop by 40 DAS) and smallflower umbrella sedge (85% control by 20 DAS) while Prowl suppressed the emergence of germinating weeds. The tank mixture of Prowl H2O (2pt/a), Granite SC (2oz/a) and Clincher (15oz/a) applied with 2.5% COC at the 2-3 lsr was another good option, providing overall best grass control (99% watergrass control, 82% sprangletop control) although control of smallflower was poor (47%) and would have required a follow-up application (Table 6).

The highest-yielding treatment was the three-way tank mix of Prowl + Clincher + Granite SC + COC (2pt + 15oz + 2oz + 2.5%v/v) at the 2-3 lsr, with a yield of 8919 lb/a. Another good treatment was the three-way tank mix of Prowl + Super Wham + Clincher + COC (2pt + 4qt + 13oz + 2.5%v/v) at the 3 lsr, which had a yield of 8372 lb/a.
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 is the area covered by weeds expressed as % of the untreated control plots; i.e. low relative weed cover corresponds to a high level of weed control). Data are combined for the 2007 through 2014 drill seeded experiments at the RES. Early and late refer to applications made near the 3 leaf-stage of rice and 1-3 tillers of rice, respectively.

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.

OR-009
OR-009 (non-ionic surfactant) By Oro-Agri
Under a continuous flood, SuperWham (6 qt/a) + OR-009 (1.25% v/v) applied at the 1-2 tiller stage of rice controlled watergrass (68%), ricefield bulrush (13%), smallflower (100%) and ducksalad (95%) (Table 2, Treatment 15). When SuperWham was applied with a generic crop oil concentrate, at the same timing and rate, control of watergrass, and ducksalad were slightly lower (66%, and 52%, respectively). Yields were significantly higher with the OR-009 (7762 lb/a) in comparison to the generic crop oil (5479 lb/a). Further field testing will continue in 2015.

RiceEdge
RiceEdge® (dry flowable mixture of propanil and halosulfuron) by RiceCo, LLC
RiceEdge® was tested under a continuous flood and a pinpoint flood (drained for one week at the 3-4 lsr). In both trials, it was applied at the highest label rate, of 10 lb/a (+ 1.25% v/v COC) at the 1-2 tiller stage of rice. In the continuous flood, it controlled watergrass (73%), and had excellent control of both ricefield bulrush and smallflower (100%) (Table 2, Treatment 16). In the pinpoint, the same rate and timing controlled 60% of watergrass, and had excellent control of ricefield bulrush and smallflower (95% and 100%) (Table 4, Treatments 2). Phytotoxicity was low (5%-10% tip burn across all treatments). The mixture did not perform well when applied at a later timing (40 DAS) (Table 2, Treatment 17, and Table 4, Treatment 3). Yields were best at the earlier application timing in both trials, reflecting the better weed control. Yield was 7841 lb/a in the continuous flood, and 8109 lb/a in the pinpoint trial.

League MVP (V-10219A, B and C)
League MVP® (granular mixture of thiobencarb and imazosulfuron) By Valent
This year, we tested two new League MVP® formulations against the commercial formulation (Table 7), one with a higher concentration of imazosulfuron (10% +1%) (V-10219B), and one with a higher concentration of both thiobencarb and imazosulfuron (11.67% +1%) (V-10219C) in comparison to the current commercial formulation (10% +0.43%) (V-10219A). Under a continuous flood, League MVP® (30lb/a) of the currently commercial formulation (V-10219A) applied into the water at the 1 leaf stage of rice (lsr) fully controlled ricefield bulrush, smallflower and ducksalad. Control of watergrass was excellent, at 98% (at 40 DAS). Applied at 30lb/A at the 2 lsr, the current commercial formulation (V-10219A) continued to give excellent broad-spectrum control, although phytotoxicity was higher than at the 1 lsr (some stand reduction). The new formulation with 11.67% thiobencarb +1% imazosulfuron (V-10219C), applied at the same rate (30lb/a) had excellent control of the same weed species at both the 1 lsr and 2 lsr. Higher stand reduction was observed with the higher percentage of
For fields with multiple-herbicide-resistant watergrass, a follow-up application of Regiment (0.8 oz/a) at the 1-2 tiller stage of rice will improve control. At a later timing (3 lsr), both formulations provided excellent control of watergrass at 40 DAS (over 97%), ricefield bulrush and smallflower (100%), though ducksalad control was lower than at the earlier timings (58% in comparison to over 90%). Phytotoxicity was low at the later application timing (3 lsr) (less than 3% injury). Yields were best with the formulation with the increased imazosulfuron, but the same rate of thiobencarb (V-10219B), with the 2 and 3 lsr applications having the best yields in the trial (8670 and 8603 lb/a, respectively).

GWN-10380 is a Gowan Co. granular mixture of benzobicyclon and halosulfuron

GWN-10380, a granular formulation of 3% benzobicyclon and 0.64% halosulfuron was tested under a continuous flood, both alone and in a program (Table 8) at the Hamilton Road site at the RES, as well as at the site in Yuba County (discussed later in the report). Phytotoxicity on rice was low (less than 10% across all categories: stunting, stand reduction, bleaching and injury). The granular formulation of GWN-10380 (7.5lb/a) applied at the 1 lsr had good watergrass control (97%) early in the season (June 20, 20 DAS) and excellent ricefield bulrush, smallflower and ducksalad control. By 40 days after seeding (July 10), watergrass control was 88%. Follow-up treatments applied at the 1 tiller stage helped maintain the early high level of watergrass control. Thus SuperWham + Grandstand (6qt/a + 8oz/a+ 1.25% v/v COC), Regiment (0.67oz/a + 2.0% v/v UAN + 0.2% v/v NIS), or Granite SC (2oz/a + 1.25% v/v COC) provided 100% watergrass control. Redstem control was best when Grandstand was used. Rice bleaching was high (80% at 7 DAT with Cerano) and 20% stand reduction was observed, but broad-spectrum weed control was best with the sequence of Cerano (12lb/a) followed by GWN-10380 (7.5 lb/a) at 1lsr (Table 8). Yields were best in the treatments with GWN-10380 fb. SuperWham + Grandstand + COC (7.5lb fb. 6qt + 8oz + 1.25%v/v) and GWN-10380 fb. Granite SC + COC (7.5lb fb. 2.8 oz + 1.25% v/v), which had yields of 8720 lb/a and 8326 lb/a, respectively.
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<th>Brand name</th>
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<td>RiceEdge</td>
<td>propanil + halosulfuron-methyl</td>
</tr>
<tr>
<td>Roundup</td>
<td>glyphosate</td>
</tr>
<tr>
<td>Sandea</td>
<td>halosulfuron-methyl</td>
</tr>
<tr>
<td>Sonar A.S.</td>
<td>fluridone</td>
</tr>
<tr>
<td>Sonar-Q</td>
<td>fluridone</td>
</tr>
<tr>
<td>Tide</td>
<td>clethodim</td>
</tr>
<tr>
<td>League MVP (V-10219)</td>
<td>thiobencarb + imazosulfuron</td>
</tr>
<tr>
<td>GWN-9796</td>
<td>benzobicyclon</td>
</tr>
<tr>
<td>GWN-10380</td>
<td>benzobicyclon + halosulfuron-methyl</td>
</tr>
<tr>
<td>OR-009</td>
<td>surfactant</td>
</tr>
</tbody>
</table>
Table 2 Continuous Flood Trial 1

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Rate</th>
<th>Prod./a</th>
<th>1st</th>
<th>2nd</th>
<th>3rd</th>
<th>24-Oct</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(g ai/ha)</td>
<td>Prod./a</td>
<td>1st</td>
<td>2nd</td>
<td>3rd</td>
<td>24-Oct</td>
</tr>
<tr>
<td>1.</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>2.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td></td>
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<td></td>
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<td></td>
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</tr>
<tr>
<td>4.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Continuous Flood Trial 1**

- **GWN-10380**: is a granular formulation of 3% benzobicyclon and 0.64% halosulfuron.
- **OR-009**: is a non-ionic surfactant.
- **RiceEdge**: is a dry flowable herbicide with 60% propanil and 0.46% halosulfuron.
- **HR**: is a granular formulation of 3% benfloxuron and 0.64% halosulfuron.

**Phytotoxicity**

- 1% Stand (Percent stand reduction)
- 1% Bleach
- 1% Injury

**LSD** = 0.05

**Yield (lb/A)**

- **ECHPH**: Echinochloa phyllopoda
- **SCPMU**: Sparganium erectum
- **CYPDI**: Cyperus difformis
- **HETLI**: Hydrocharis morsus-ranae

**Seedling**

- 0 = No seedlings
- 1 = 1 seedling
- 2 = 2 seedlings

**Date of application**

- 10-Jul (% of flowering)
- 23-Jun (% of flowering)
- 6-Jun (% of flowering)

**Weather conditions**

- 0.6 MPH from the South
- 3.0 MPH from the Northwest
- 2.5 MPH from the Southeast
- 5.0 MPH from the Northwest

**Timing**

- 10-Jul (40 DAS
- 23-Jun (20 DAS
- 6-Jun (20 DAS

**Application timing**

- **Seedling**
- 0 = No seedlings
- 1 = 1 seedling
- 2 = 2 seedlings

**Field condition**

- 0 = No seedlings
- 1 = 1 seedling
- 2 = 2 seedlings

**Spray applications**

- With 40 gallons/acre using 8000 nozzles
- 100 lbs ammonium sulfate + 2% water

**HR** = 2% water

**Duration**

- 10-Jun (20 DAS
- 13-Jun (20 DAS
- 18-Jun (20 DAS

**Experimental design**

- **2** = Two treatments
- **3** = Three treatments
- **4** = Four treatments

**Experiment**

- 10-Sep (20 DAS
- 13-Sep (20 DAS

**Timing**

- 10-Sep (20 DAS
- 13-Sep (20 DAS

**Descriptive statistics**

- **LSD** = 0.05

**Continuous Flood**

- **Application timing**
- **Seedling**
- **Field condition**

**Day of seeding Application**

- **June**

**Post-Flood Applications**

- **June**: 6, 10, 13, 16, 18, 23, 25, 27, 29, 30, **July**

**Spray applications**

- With 40 gallons/acre using 8000 nozzles
- 100 lbs ammonium sulfate + 2% water

**Overall**

- **HR** = 2% water

**Conclusion**

- HR treatment was superior in controlling weeds compared to the control treatment.
### Table 3. Continuous Flood Trial 2

#### HR Continuous Flood Trial 2

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Rate (g ai/ha)</th>
<th>Prod./a</th>
<th>1st Timing1</th>
<th>2nd Timing</th>
<th>Application date</th>
<th>% Injury</th>
<th>% Bleach</th>
<th>% Stand</th>
<th>% Stunting</th>
<th>% Injury</th>
<th>% Bleach</th>
<th>% Stand</th>
<th>% Stunting</th>
<th>% Injury</th>
<th>% Bleach</th>
<th>% Stand</th>
<th>% Stunting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Untreated</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
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<td>---</td>
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<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Cerano</td>
<td>580</td>
<td>10 lb</td>
<td>DOS-2-Jun</td>
<td>---</td>
<td>---</td>
<td>0</td>
<td>0</td>
<td>20</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>20</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td>Cerano fb. Halomax + Shark H2O</td>
<td>560 lb, 52.5 + 106 lb</td>
<td>10 lb fb. 1oz + 7oz</td>
<td>DOS fb. 2-3 lsr 2-Jun</td>
<td>11-Jun</td>
<td>0 0 29 0 0 22 2</td>
<td>1 2 16 7 0 7 3</td>
<td>80 93 95 98</td>
<td>97 100 100 99</td>
<td>97 96 75</td>
<td>5972</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cerano fb. Halomax + Shark H2O</td>
<td>560 lb, 69.8 + 196 lb</td>
<td>10 lb fb. 1.33oz + 7oz</td>
<td>DOS fb. 2-3 lsr 2-Jun</td>
<td>11-Jun</td>
<td>0 0 38 0 0 19 2</td>
<td>0 1 5 5 0 3 3</td>
<td>83 81 99 98</td>
<td>99 100 100 100</td>
<td>98 100 100</td>
<td>6034</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bolero</td>
<td>3867</td>
<td>23 lb</td>
<td>1/2 lsr</td>
<td>6-Jun</td>
<td>0 0 2 0 2 12 24 6 9</td>
<td>--- --- ---</td>
<td>--- --- ---</td>
<td>--- --- ---</td>
<td>--- --- ---</td>
<td>--- --- ---</td>
<td>--- --- ---</td>
<td>--- --- ---</td>
<td>--- --- ---</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bolero fb. Halomax + Shark H2O</td>
<td>3867 lb, 52.5 + 196 lb</td>
<td>23 lb fb. 1oz + 7oz</td>
<td>1-2 lsr fb. 2-3 lsr 6-Jun</td>
<td>11-Jun</td>
<td>3 1 0 2 16 20 2</td>
<td>0 0 1 2</td>
<td>0 3 0 2</td>
<td>91 100 100 100</td>
<td>96 100 100 100</td>
<td>100 100 88</td>
<td>6607</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bolero fb. Halomax + Shark H2O</td>
<td>3867 lb, 69.8 + 196 lb</td>
<td>23 lb fb. 1.33oz + 7oz</td>
<td>1-2 lsr fb. 2-3 lsr 6-Jun</td>
<td>11-Jun</td>
<td>0 3 0 2 21 23 6</td>
<td>1 0 0 2</td>
<td>0 2 0 1</td>
<td>92 95 100 100</td>
<td>98 100 100 100</td>
<td>94 100 100</td>
<td>6731</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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. 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 1, 2014 with 120 lbs per acre of M205
3. No weeds had emerged on June 2 (DOS application).
4. Weather conditions on June 2: Air temperature 84.5°F, water temperature was 80.6°F, wind 3.1 MPH from the southwest.
5. Weather conditions on June 6: Air temperature 76.4°F, water temperature 80.4°F, wind 6.5 MPH from the north.
6. Weather conditions on June 11: Air temperature 88.5°F, water temperature 89.6°F, wind 9.8 MPH from the southeast.
7. Spray applications made with 20 gallons/acre using 8003 nozzles.
8. July 21, 2014- 100lb ammonium sulfate = 21lb nitrogen/acre

![Continuous Flood](image)
## Table 4. Pinpoint Trial

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Rate</th>
<th>Prod. a</th>
<th>Timing</th>
<th>Application date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice Edge + COC</td>
<td>6726 + 52</td>
<td>10 lb + 2.5% v/v</td>
<td>40-75 DAS (60)</td>
<td>23-Jun</td>
</tr>
<tr>
<td>Rice Edge + COC</td>
<td>6726 + 52</td>
<td>10 lb + 2.5% v/v</td>
<td>60 DAS (112 Til)</td>
<td>10-Jul</td>
</tr>
<tr>
<td>Clincher + Granite SC + COC</td>
<td>6726</td>
<td>6 lb + 1.5% v/v</td>
<td>4-yr.</td>
<td>16-Jun</td>
</tr>
<tr>
<td>Clincher + Granite SC + COC</td>
<td>6726</td>
<td>6 lb + 1.5% v/v</td>
<td>3-yr.</td>
<td>16-Jun</td>
</tr>
<tr>
<td>Clincher + Granite SC + COC</td>
<td>35 lb</td>
<td>13oz + 2.5% v/v</td>
<td>3-yr.</td>
<td>16-Jun</td>
</tr>
<tr>
<td>SuperWham + Clincher + COC</td>
<td>6726</td>
<td>6 lb + 1.5% v/v</td>
<td>4-yr.</td>
<td>16-Jun</td>
</tr>
<tr>
<td>SuperWham + Clincher + COC</td>
<td>6726</td>
<td>6 lb + 1.5% v/v</td>
<td>3-yr.</td>
<td>16-Jun</td>
</tr>
<tr>
<td>Regent + UAN + NIS</td>
<td>37.5 lb</td>
<td>210 lb + 2.5% v/v</td>
<td>3-yr.</td>
<td>16-Jun</td>
</tr>
<tr>
<td>Clincher + Granite SC + COC + Regent + UAN + NIS</td>
<td>6726</td>
<td>6 lb + 1.5% v/v</td>
<td>4-yr.</td>
<td>16-Jun</td>
</tr>
<tr>
<td>Clincher + Granite SC + COC + Regent + UAN + NIS</td>
<td>6726</td>
<td>6 lb + 1.5% v/v</td>
<td>3-yr.</td>
<td>16-Jun</td>
</tr>
</tbody>
</table>

### LSD = 0.05

### Rice Edge is a dry flowable herbicide with 60% propanil and 0.46% haloxyfuron.

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)

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

Untreated weed control values represent % cover by the respective weed species.

### Trial Information

1. Trial seeded June 1, 2014 with 120 lbs per acre of M205
2. Trial managed as a pinpoint: drained June 10, and reflooded June 18.
3. Watergrass was 3-5 leaf, bulrush was 2 leaf, smallflower was 1.2 inches, water hydrop is 2.4 leaf, and duckweed was 4 leaf, on June 16.
4. Weather conditions on June 16: Air temperature 77° F, wind 6 MPH from the Southwest.

Weather conditions on June 19: Air temperature 82° F, wind 1 MPH from the south.

Weather conditions on June 23: Air temperature 89° F, water temperature 84° F, wind 3 MPH from the southeast.

Weather conditions on July 2: Air temperature 87° F, wind 2 MPH from the southeast.

Spray applications made with 20 gallons/acre using 8003 nozzles.

Table 5. Shark H₂O Foliar

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Rate</th>
<th>Timing³</th>
<th>Application date</th>
<th>1st</th>
<th>2nd</th>
<th>3rd</th>
<th>7 DAT</th>
<th>14 DAT</th>
<th>21 DAT</th>
<th>28 DAT</th>
<th>35 DAT</th>
<th>42 DAT</th>
<th>LSD 1214</th>
</tr>
</thead>
<tbody>
<tr>
<td>Untreated</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>Cerano fb. Shark H2O fb. SuperWham + COC</td>
<td>6.73 lbs. + 2.1 lbs. + 0.75 lbs.</td>
<td>2-Jun 13-Jun 2-Jul</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1.25% v/v</td>
<td>7320</td>
</tr>
<tr>
<td>Cerano fb. Shark H2O fb. Shark H2O</td>
<td>6.73 lbs. + 2.1 lbs.</td>
<td>2-Jun 13-Jun 2-Jul</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1.25% v/v</td>
<td>6529</td>
</tr>
<tr>
<td>Cerano fb. Lupine fb. Shark H2O</td>
<td>6.73 lbs. + 2.1 lbs.</td>
<td>2-Jun 13-Jun 2-Jul</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1.25% v/v</td>
<td>6377</td>
</tr>
<tr>
<td>Cerano fb. Haloxite fb. Shark H2O</td>
<td>6.73 lbs. + 2.1 lbs.</td>
<td>2-Jun 13-Jun 2-Jul</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1.25% v/v</td>
<td>7016</td>
</tr>
</tbody>
</table>

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 (bistort)
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 1, 2014 with 120 lbs per acre of M205.
2. Trial managed as a pinpoint: drained June 10, and reflooded June 15.
3. No weeds had emerged on June 2 (DOS application).
Watergrass was 2.5 leaf, bulrush was 4 leaves, smallflower was 1 inch, and ducksalad was 2 inches, on June 13.
4. Weather conditions on June 2: Air temperature 84.5°F, water temperature was 80.6°F, wind 3.1 MPH from the southwest.
Weather conditions on June 13: Air temperature 80°F F, wind 6 MPH from the northwest.
Weather conditions on July 2: Air temperature 84°F F, water temperature 84.5°F, wind 3 MPH from the southeast.
5. Spray applications made with 20 gallons/acre using 8003 nozzles.
6. July 21, 2014- 100lb ammonium sulfate = 21lb nitrogen/acre

Phytotoxicity
- Phytotoxicity 1
- Phytotoxicity 2
- Phytotoxicity 3
- Phytotoxicity 4

Weed Control
- Weeds Control 1
- Weeds Control 2
- Weeds Control 3
- Weeds Control 4

Project No. RP-1
### Table 6. Drill-Seeded Trial

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Rate (g ai/ha)</th>
<th>Post (a)</th>
<th>Timing</th>
<th>Application date</th>
<th>Yield (lb/A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Untreated</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peak ECHPH + Super Wham + Clincher + COC</td>
<td>1120 2pt 3 lsr</td>
<td></td>
<td></td>
<td>13-Jun</td>
<td>0 25 33 0 35 81 7 0 14 0 2077</td>
</tr>
<tr>
<td>Abolish + Regiment + UAN + NIS</td>
<td>1120 2pt 3 lsr</td>
<td></td>
<td></td>
<td>13-Jun</td>
<td>98 85 94 98 61 51 88 96 99 30 8372</td>
</tr>
<tr>
<td>Prowl H2O + Abolish + Regiment + UAN + NIS</td>
<td>1120 2pt 3 lsr</td>
<td></td>
<td></td>
<td>19-Jun</td>
<td>0 25 33 0 35 81 7 0 14 0 2077</td>
</tr>
<tr>
<td>Prowl H2O + Abolish + Regiment + UAN + NIS</td>
<td>1120 2pt 3 lsr</td>
<td></td>
<td></td>
<td>29-May</td>
<td>0 35 88 100 0 0 94 97 100 0 8101</td>
</tr>
<tr>
<td>Prowl H2O + Abolish + Regiment + UAN + NIS</td>
<td>1120 2pt 3 lsr</td>
<td></td>
<td></td>
<td>13-Jun</td>
<td>85 47 99 100 82 47 97 100 100 54 8919</td>
</tr>
<tr>
<td>Prowl H2O + Abolish + Regiment + UAN + NIS</td>
<td>1120 2pt 3 lsr</td>
<td></td>
<td></td>
<td>29-May</td>
<td>0 25 33 0 35 81 7 0 14 0 2077</td>
</tr>
<tr>
<td>Prowl H2O + Abolish + Regiment + UAN + NIS</td>
<td>1120 2pt 3 lsr</td>
<td></td>
<td></td>
<td>19-Jun</td>
<td>0 25 33 0 35 81 7 0 14 0 2077</td>
</tr>
<tr>
<td>Prowl H2O + Abolish + Regiment + UAN + NIS</td>
<td>1120 2pt 3 lsr</td>
<td></td>
<td></td>
<td>29-May</td>
<td>0 35 88 100 0 0 94 97 100 0 8101</td>
</tr>
<tr>
<td>Prowl H2O + Abolish + Regiment + UAN + NIS</td>
<td>1120 2pt 3 lsr</td>
<td></td>
<td></td>
<td>13-Jun</td>
<td>85 47 99 100 82 47 97 100 100 54 8919</td>
</tr>
<tr>
<td>Prowl H2O + Abolish + Regiment + UAN + NIS</td>
<td>1120 2pt 3 lsr</td>
<td></td>
<td></td>
<td>29-May</td>
<td>0 35 88 100 0 0 94 97 100 0 8101</td>
</tr>
<tr>
<td>Prowl H2O + Abolish + Regiment + UAN + NIS</td>
<td>1120 2pt 3 lsr</td>
<td></td>
<td></td>
<td>13-Jun</td>
<td>85 47 99 100 82 47 97 100 100 54 8919</td>
</tr>
</tbody>
</table>

**LSD = 0.05**

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), ECHCR (Barnyardgrass), CYPDI (Small flower Umbrellaplant), HETLI (Duck salad)
LEFFA (Sprangletop), BAORO (Waterhyssop), AMMCO (Redstem), SAGMO (California arrowhead), MOOVA (Monochoria)
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 drill-seeded May 28, 2014 with 120 lbs per acre of M205
2. Initial flush was May 29, followed by flushes June 4 and June 8. A permanent flood was applied June 15.
3. Pre-weeds had emerged on May 29 (PRE application)
4. Weather conditions on June 13: Air temperature 79°F, wind 0.67 MPH from the South.
5. Spray applications made with 20 gallons/acre using 8003 nozzles.
6. July 21, 2014- 100 lb ammonium sulfate + 2 lb nitrate/cane
Table 7 Valent Continuous Flood Trial

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Rate</th>
<th>Timing¹</th>
<th>Application date</th>
<th>% Stand</th>
<th>% Bleach</th>
<th>% Injury</th>
<th>% Stunting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Untreated</td>
<td></td>
<td></td>
<td></td>
<td>96</td>
<td>99</td>
<td>96</td>
<td>99</td>
</tr>
<tr>
<td>Overseed</td>
<td></td>
<td></td>
<td></td>
<td>96</td>
<td>99</td>
<td>96</td>
<td>99</td>
</tr>
<tr>
<td>V-10219 A</td>
<td>3363 + 144 lb, 37.5</td>
<td>1st</td>
<td>1st</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>V-10219 B</td>
<td>3363 + 144 lb, 37.5</td>
<td>2nd</td>
<td>2nd</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>V-10219 C</td>
<td>3363 + 144 lb, 37.5</td>
<td>3rd</td>
<td>3rd</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

¹ Timing: 1st application on May 31, 2nd application on June 9, 3rd application on July 7.
² LSD = 0.05

The table provides a detailed overview of the weed control values and the timing of applications for the Valent Continuous Flood Trial. The trial was conducted with various treatments and timings, all aimed at managing weeds effectively while maintaining rice quality. The data includes the percentage of stand, bleach, injury, and stunting, with LSD values indicating the significance of these measurements. The trial information includes the method of application and the weed control outcomes, highlighting the effectiveness of the treatments over different stages of rice growth. The table also references specific weed species and their control percentages, underscoring the comprehensive approach to weed management in this experimental setup.
Table 8 Gowan Continuous Flood Trial

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Rate</th>
<th>Timing3</th>
<th>Application date</th>
<th>Phytotoxicity</th>
<th>Weed Control2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(g ai/ha)</td>
<td>Prod. a</td>
<td>1st 2nd</td>
<td>7 DAT</td>
<td>14 DAT</td>
</tr>
<tr>
<td>Untreated4</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>GWN-9796 + Sandea</td>
<td>250 + 52.5</td>
<td>57oz + 1st</td>
<td>1 lsr</td>
<td>June 6</td>
<td>2-Jul</td>
</tr>
<tr>
<td>GWN-10380</td>
<td>250 + 52.5</td>
<td>7.5lb</td>
<td>1 lsr</td>
<td>June 6</td>
<td>2-Jul</td>
</tr>
<tr>
<td>GWN-10380 + SuperWham + Grandstand + COC</td>
<td>250 + 52.5</td>
<td>7.5lb</td>
<td>1 lsr</td>
<td>June 6</td>
<td>2-Jul</td>
</tr>
<tr>
<td>GWN-10380 + Regiment + JSN + NIC</td>
<td>250 + 52.5</td>
<td>7.5lb</td>
<td>1 lsr</td>
<td>June 6</td>
<td>2-Jul</td>
</tr>
<tr>
<td>GWN-10380 + Clincher + COC</td>
<td>250 + 52.5</td>
<td>7.5lb</td>
<td>1 lsr</td>
<td>June 6</td>
<td>2-Jul</td>
</tr>
<tr>
<td>GWN-10380 + Granite SC + COC</td>
<td>250 + 52.5</td>
<td>12 lb</td>
<td>1 lsr</td>
<td>June 6</td>
<td>2-Jul</td>
</tr>
<tr>
<td>Cerano + GWN-10380</td>
<td>673 lb + 52.5</td>
<td>10 lb</td>
<td>1 lsr</td>
<td>June 6</td>
<td>2-Jul</td>
</tr>
</tbody>
</table>

GWN-9796 is a liquid suspension formulation consisting of 6% benzonpyriclon
GWN-10380 is a granular formulation of 3% benzonpyriclon and 0.5% halosulfuron
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 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 1, 2014 with 120 lbs per acre of M205
2. Trial managed as a continuous flood with water started May 30, 2014
3. No weeds had emerged on June 2 (DOS application)
Watergrass was 1.5 leaf, bulrush was 1 inch, and duckweed was 2 leaf, on June 6.
Watergrass was 2-3 tiller, bulrush was 2 tiller, smallflower was 5-6 inches, waterhyssop was 4-6 nodes, monochoria was 2-3 leaves,
arrowhead was flowering, and duckweed was flowering, on July 2.
4. Weather conditions on June 2: Air temperature 84.5F, water temperature was 80.6o F, wind 3.1 MPH from the southwest.
Weather conditions on June 6: Air temperature 71°F, water temperature 69.8°F, wind 3.3 MPH from the south.
Weather conditions on July 2: Air temperature 82°F, water temperature 77°F, wind 2.5 MPH from the Southwest.
5. Spray applications made with 20 gallons/acre using 8003 nozzles.
6. Liquid applications of GWN-9796 were made with 10 foot boom with nozzles removed.
7. July 21, 2014- 100lb ammonium sulfate = 24 lb nitrogen/acre

Gowan Demo. Continuous Flood

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LSD = 0.05
728
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. This includes the development of a weed germination and emergence prediction approach for the adequate Timing of Weed Control and also for use in stale-seedbed systems.

3.1. Introduction of new total herbicide options
We are continuing to evaluate potential new herbicides, particularly for the management of herbicide-resistant weeds. Sonar-Q (a granular formulation of 5% fluridone) and Sonar A.S. (a flowable formulation of 41.7% fluridone) are aquatic herbicides currently registered in California for other crops as well as for weed management in waterways. We evaluated their potential for weed control, as well as for phytotoxicity on rice. Fluridone is a carotenoid synthesis inhibitor, but it does not act on the same part of the pathway as clomazone, so there is potential for it to control clomazone-resistant weeds (sprangletop and watergrass).

3.1.a. Evaluation of Sonar (fluridone) in the field and greenhouse

Greenhouse Trial
We tested the Sonar A.S., (a flowable formulation of 41.7% fluridone) in the greenhouse to see the efficacy on the following weeds: susceptible and multiple-herbicide resistant late watergrass (*Echinochloa phyllopogon*), susceptible and clomazone resistant bearded sprangletop (*Leptochloa fusca* spp. *fascicularis*), susceptible and ALS- and propanil-resistant smallflower umbrella sedge (*Cyperus difformis*), and susceptible and ALS- and propanil-resistant ricefield bulrush (*Schoenoplectus mucronatus*). We also tested rice variety M-206, for phytotoxicity. Rates tested were 0, 9, 19, 38, 75, 151, 301, and 1205 g ai/ha of Sonar A.S. (fluridone).

Methods
Plants were grown in 3-inch pots filled with stock soil (Stockton clay adobe soil) and topped with 1 inch of sterilized soil. The pots were placed in enough water to allow moisture to be absorbed (water level was kept below the soil surface). Seeds of sprangletop, ricefield bulrush, and smallflower umbrella sedge were seeded directly on the wet soil. After germination, each pot was thinned down to 5 plants. Late watergrass was pre-germinated in an incubator and transplanted into pots (5 plants each). Pots were placed into plastic tubs with 3-mil plastic liner and then tubs were flooded to 4 inches above the soil surface. Sonar A.S. was then evenly applied to the surface of the water when plants were at the 1-2 leaf stage. Each treatment-biotype combination was replicated 6 times (6 pots containing 5 plants each).

Greenhouse conditions in June, 2014 were as follows: average maximum daily temperature of the greenhouse in June, 2014 was 99° F (±5° F), and the average minimum was 73° F (±5° F). The average maximum relative humidity (RH) was 85% (±4%), and the average minimum was 26% (±7%). For the month of August, the average maximum temperature was 99° F (±3° F), and the average minimum was 75° F (±1° F). The average maximum relative humidity (RH) was 87% (±5%) while the average minimum was 31% (±5%).

The average irradiance (at plant height) was between approximately 400 µmol s⁻¹ m⁻² (morning) to approximately 1000 µmol s⁻¹ m⁻² (midday). Daylight hours were fixed at 16 hours of light and 8 hours of dark using metal halide lights (to simulate rice-growing season conditions).

Surviving plants were harvested 20 days after application. The number of plants and the fresh
weight of the aboveground biomass were recorded. Plants were then dried at 30° C for a week and their dry weight was also recorded. Percent control was calculated in reference to untreated checks, for both fresh and dry weights.

Results
All species and biotypes (both resistant and susceptible) were 100% controlled by 151 g ai/ha (fluridone) (Table 9). Unfortunately, this also included rice (variety M-206), which was 98% dead at 151 g ai/ha. The two clomazone-resistant biotypes (of sprangletop and late watergrass) were also 100% controlled at 151 g ai/ha, which indicates that it may be a good substitute for Cerano-based programs in clomazone-resistant sites.

Table 9. Fresh weight as % of the untreated control for 8 rates of susceptible and resistant biotypes of late watergrass, sprangletop, smallflower umbrella sedge, and ricefield bulrush, as well as rice variety M-206.

<table>
<thead>
<tr>
<th>Fluridone Treatments (g ai/ha)</th>
<th>0</th>
<th>9</th>
<th>19</th>
<th>38</th>
<th>75</th>
<th>151</th>
<th>301</th>
<th>1205</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Late Watergrass</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S 100 (±0)</td>
<td>95 (±4)</td>
<td>54 (±19)</td>
<td>28 (±13)</td>
<td>0 (±0)</td>
<td>0 (±0)</td>
<td>0 (±0)</td>
<td>0 (±0)</td>
<td></td>
</tr>
<tr>
<td>R 100 (±0)</td>
<td>80 (±9)</td>
<td>50 (±15)</td>
<td>30 (±12)</td>
<td>11 (±7)</td>
<td>0 (±0)</td>
<td>0 (±0)</td>
<td>0 (±0)</td>
<td></td>
</tr>
<tr>
<td><strong>Sprangletop</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S 100 (±0)</td>
<td>90 (±5)</td>
<td>95 (±4)</td>
<td>72 (±14)</td>
<td>52 (±17)</td>
<td>0 (±0)</td>
<td>0 (±0)</td>
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<td></td>
</tr>
<tr>
<td>R 100 (±0)</td>
<td>52 (±16)</td>
<td>67 (±12)</td>
<td>3 (±2)</td>
<td>0 (±0)</td>
<td>0 (±0)</td>
<td>0 (±0)</td>
<td>0 (±0)</td>
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</tr>
<tr>
<td><strong>Smallflower Umbrella Sedge</strong></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S 100 (±0)</td>
<td>68 (±16)</td>
<td>48 (±21)</td>
<td>30 (±15)</td>
<td>7 (±7)</td>
<td>0 (±0)</td>
<td>0 (±0)</td>
<td>0 (±0)</td>
<td></td>
</tr>
<tr>
<td>R 100 (±0)</td>
<td>67 (±15)</td>
<td>69 (±17)</td>
<td>67 (±14)</td>
<td>21 (±16)</td>
<td>0 (±0)</td>
<td>2 (±2)</td>
<td>0 (±0)</td>
<td></td>
</tr>
<tr>
<td><strong>Ricefield Bulrush</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S 100 (±0)</td>
<td>71 (±12)</td>
<td>55 (±17)</td>
<td>17 (±5)</td>
<td>4 (±2)</td>
<td>0 (±0)</td>
<td>0 (±0)</td>
<td>0 (±0)</td>
<td></td>
</tr>
<tr>
<td>R 100 (±0)</td>
<td>66 (±12)</td>
<td>45 (±18)</td>
<td>29 (±14)</td>
<td>0 (±0)</td>
<td>0 (±0)</td>
<td>0 (±0)</td>
<td>0 (±0)</td>
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</tr>
<tr>
<td><strong>Rice Variety M-206</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>M-206 100 (±0)</td>
<td>92 (±4)</td>
<td>64 (±13)</td>
<td>55 (±11)</td>
<td>36 (±18)</td>
<td>2 (±2)</td>
<td>0 (±0)</td>
<td>0 (±0)</td>
<td></td>
</tr>
</tbody>
</table>

Field Trial
Sonar-Q (a granular formulation of 5% fluridone) was applied at three rates at the 1 lsr into a continuous flood trial planted with M-206 (Table 10). As expected, there was significant bleaching, with a significant rate response (38% at the highest rate) by 7 days after treatment, though rice had recovered by 14 days after treatment. Stand reduction was low (2% or less). The herbicide appears to have moderate broad-spectrum control, although the control was best at 20 days after seeding, with a significant number of escapes by 60 DAS. Due to poor early weed control, yields were low (around 4000 lb/a) across all treatments. Although visual assessments of phytotoxicity were low, there may have been injury to the rice that affected yields.
This formulation of fluridone may be useful as a broad-spectrum herbicide as part of a program, especially in resistant sites. Mixtures with Cerano are not recommended, as the two herbicides are both carotenoid inhibitors, and the combination may increase phytotoxicity on rice.

Table 10. Continuous flood field trial using Sonar-Q (fluridone)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Rate (g ai/ha)</th>
<th>Prod./a</th>
<th>Timing 1 Application date</th>
<th>% Stunting</th>
<th>% Blanch</th>
<th>% Injury</th>
<th>% Stunting</th>
<th>% Blanch</th>
<th>% Injury</th>
<th>% Stunting</th>
<th>% Blanch</th>
<th>% Injury</th>
<th>% Stunting</th>
<th>% Blanch</th>
<th>% Injury</th>
<th>% Stunting</th>
<th>% Blanch</th>
<th>% Injury</th>
<th>% Stunting</th>
<th>% Blanch</th>
<th>% Injury</th>
<th>% Stunting</th>
<th>% Blanch</th>
<th>% Injury</th>
<th>% Stunting</th>
<th>% Blanch</th>
<th>% Injury</th>
<th>% Stunting</th>
<th>% Blanch</th>
<th>% Injury</th>
</tr>
</thead>
<tbody>
<tr>
<td>Untreated</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td>0</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sonar-Q (Fluridone)</td>
<td>37.5</td>
<td>10.7oz</td>
<td>1 lsr 6-Jun</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>27</td>
<td>59</td>
<td>44</td>
<td>83</td>
<td>0</td>
<td>0</td>
<td>69</td>
<td>83</td>
<td>7</td>
<td>10</td>
<td>65</td>
<td>92</td>
<td>4773</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sonar-Q (Fluridone)</td>
<td>75</td>
<td>21.4oz</td>
<td>1 lsr 6-Jun</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>29</td>
<td>20</td>
<td>50</td>
<td>54</td>
<td>0</td>
<td>0</td>
<td>33</td>
<td>50</td>
<td>8</td>
<td>1</td>
<td>0</td>
<td>13</td>
<td>4063</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Sonar-Q (Fluridone)</td>
<td>150</td>
<td>42.8oz</td>
<td>1 lsr 6-Jun</td>
<td>0</td>
<td>0</td>
<td>32</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>7</td>
<td>0</td>
<td>1</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

LSD = 0.05

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 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 1, 2014 with 120 lbs per acre of M205
3. Watergrass was 1.5 leaf, bulrush was 1 inch, and ducksalad was 2 leaf, on June 6.
4. Weather conditions on June 6: Air temperature 76.4o F, water temperature 80.4o F, wind 8.5 MPH from the North.
5. July 21, 2014- 100lb ammonium sulfate = 21lb nitrogen/acre

Fluridone may be a good option for broad-spectrum control of both resistant and susceptible weeds. However, work will need to be done to figure out the best formulation, as well as the optimal field rate, to increase efficacy and reduce phytotoxicity. Sonar A.S. killed rice in the greenhouse, but Sonar-Q appeared to have less phytotoxicity on rice than Sonar A.S. (using the same rice variety, M-206), although the low yields may indicate some damage that was not visible. In addition to our tests, over the past year, several herbicide companies have also begun to work on this product in rice.

### 3.2. Prediction of weed emergence

A critical element that conditions the weed control success and adoption of the stale seedbed technique is being able to get most weeds emerged to maximize the proportion of resistant plants that are subjected to control by a total non-selective herbicide (so far we have been using glyphosate) leaving fewer seeds in the soil capable of emerging later. Another critical factor is to be able to achieve this with a minimum of pre-plant irrigation time to avoid an excessive delay in planting rice; this represents a major uncertainty to growers. In addition, new herbicide-resistance problems have been detected (such as propanil resistance in sedges), which aggravate even more the critical situation of chemical weed control in California rice.

However, upon testing growers’ samples for resistance trying to determine herbicide options that can still work in these fields, we often have a sizeable number of samples brought to us that are not resistant, yet growers report control failures in the field. This often results from poor timing of control, particularly since many of the herbicides currently available have a narrow window of control. The optimum timing of control for maximum efficacy of our herbicides is known to us from experimentation, but we have poor knowledge of our weed emergence patterns and how these are affected by environmental and crop management practices. Thus often we may not always be applying herbicides when weeds are at the optimum stage, which is
not always easy to establish when we grow rice over extended areas or in fields under different conditions of temperature, soil and water availability.

To address these issues of adequate timing of control with conventional in-crop herbicides (either soil-acting or foliarly-applied) or in pre-plant in conjunction with a stale seedbed technique for ‘mimic’, my lab has developed germination and emergence models for smallflower and late watergrass (“mimic”), based on temperature and soil moisture. The benefit to creating these models has been the ability to predict weed emergence based on soil or air temperature (accumulation of degree-days in the spring) and moisture according to different irrigation practices. However, before these models can be used as tools to assist farmers in scheduling their weed control, more information to use in constructing the models is needed.

3.2.a. Validation of Late Watergrass and Smallflower Umbrella sedge models in the field

Introduction

The development of herbicide resistance in major weed species of rice in California, including *Cyperus difformis* L. (smallflower umbrella sedge) and *Echinochloa phyllopogon* (Stapf) Koss (late watergrass), has necessitated the search for management options that utilize cultural controls. In order to effectively apply these controls (including stale seedbed and intermittent irrigation), weed germination and emergence need to be observed under a variety of tillage and irrigation methods. Laboratory-developed models of germination and emergence for *C. difformis* and *E. phyllopogon* have accurately predicted timing of germination and emergence using soil moisture and temperature (hydro- and thermal-time models) in controlled environments. In order to be able to use these models in the field to accurately predict emergence, validation under field conditions is required.

Methods

In 2013 and again in 2014, two locations known to have large seedbanks with susceptible populations of *Cyperus difformis* and *Echinochloa phyllopogon* were selected. Beginning from the initial flood or flush, daily counts of emerged seedlings were conducted under two irrigation treatments (3 replications): Continuously Flooded (water maintained at 10 cm above the soil), and Flushed (flush irrigated when top layer of soil became dry). Three 25-cm² quadrats were placed in each of the plots, for a total of nine quadrats per irrigation treatment, per species. Plants were removed at each count until no more plants emerged (45 days for *C. difformis*, and 40 days for *E. phyllopogon*). *C. difformis* were considered emerged when 1-2 leaves were visible, and *E. phyllopogon* were considered emerged when 1 leaf was visible (differentiated from early watergrass by absence of awn on seed). Volumetric water content (m³/m³) and air and soil temperature (°C) were recorded continuously for the duration of the counts. To compare the observed data to the laboratory-generated data, percent daily emergence was calculated per growing degree-day (GDD in °C d), using laboratory-determined average base temperature (*Tₜₘₜₜ*) for two biotypes of susceptible California *C. difformis* biotypes (18.39°C), and laboratory-determined base temperature for the susceptible biotype HR for *E. phyllopogon* (9.03 °C). Since an emergence model has not yet been developed for *C. difformis*, observed emergence was compared with predicted germination curves for *C. difformis* using the thermal time model with laboratory-generated parameters, \[ G = \frac{\log t₆ - (\log \theta_T(50) - \log (T - T_b))}{\sigma_g} \]. Observed emergence was compared with predicted emergence curves for *E. phyllopogon*. The predicted emergence curves were generated using laboratory-generated parameters for germination curves in GDD (°C d), which were then added to the GDD’s for growth to 4.5 cm above the soil surface (seed depth was assumed to be normally distributed).
Results
When expressed in growing degree-days (GDD), smallflower umbrella sedge initiated emergence earlier under the flooded irrigation treatment than under the drill-seeded (Figure 4). The rate of emergence was faster under drill seeding. This supports similar data collected in pots for smallflower umbrella sedge. There is not a difference in GDD to the beginning of emergence for late watergrass (Figure 4), which confirms what is already known about late watergrass, that it can be either an aquatic or dryland species. This supports similar data collected in pots for late watergrass.

Since laboratory models were developed under aerobic conditions, model accuracy was best for both *C. difformis* and *E. phyllopogon* under flushed irrigation (Figure 4). Differences between observed and predicted germination initiation values may be due to the assumption in *E. phyllopogon* models that seed depth for germination and emergence follow a normal distribution. In the models for both species, the assumption that accrual of hydrothermal time begins at onset of irrigation may be incorrect (it may begin earlier), and this could account for incorrect predictions of initiation of emergence.

In *C. difformis*, differences between observed and predicted values from 50% to 100% emergence values may be due to effects of anoxia on emergence under anaerobic conditions (the laboratory model was developed under aerobic conditions). For both species, there may also be differences in base temperature or base water potential for emergence (currently assumed to be the same as germination).

Data for 2014 has yet to be evaluated, but it will be compared to the data from 2013 to see if there are year-to-year differences, independent of irrigation and temperature.
3.3. Evaluation of Weed Species and Competition in Alternative Irrigation Methods

Due to looming water resource issues in California, we have been evaluating the dynamics of weed emergence in alternative irrigation systems. Since 2013, we have been evaluating three systems: i) Water-Seeded Alternate Wet and Dry (WS-AWD); ii) Drill-Seeded Alternate Wet and Dry (DS-AWD); and iii) Water-Seeded Conventional (WS-Control). Preliminary results confirm earlier results from other dry- versus wet-seeded systems. The dry-seeded system was dominated by grasses (particularly barnyardgrass and sprangletop) with a small population of smallflower umbrella sedge. The wet-seeded systems were dominated by aquatic weeds: primarily ducksalad, ricefield bulrush, and some watergrass. With full-control of weeds, yields were the same across all systems (10 t/ha). Without weed control, yields in the dry-seeded system were 0 t/ha. Without weed control, yields were not significantly different from each other in the two water-seeded systems; the WS-AWD yielded slightly lower (5 t/ha) than the WS-Control (7 t/ha).
Methods
The experiment began in 2013 at the California Rice Research Station in Biggs, CA, and continued through 2014. Data presented here is from 2013 only. It was designed as an RCBD with a split-plot treatment structure, with three replications of each treatment. The main plots were three irrigation regimes: A) Drill-Seeded Alternate Wet and Dry (DS-AWD): drill-seeded, then flushed again when Volumetric Water Content (VWC) reached 35%; B) Water-Seeded Alternate Wet and Dry (WS-AWD): flooded for initial seeding by air, and until canopy closure of the rice, allowed to drain and then flushed again when VWC reached 35%; and C) Water-Seeded Conventional (WS-Control): permanent flood of 10-15 cm, which was maintained until the field was drained approximately one month prior to harvest. Each main plot was divided into two subplots to which a weed-free (treated with post-emergent herbicides) and a weedy treatment was assigned.

The WS-AWD and WS-Control were water-seeded by air with pre-soaked seed (cv. M-205), using a seeding rate of 168 kg/ha. The DS-AWD was seeded by drill at a rate of 112 kg/ha. Planting dates corresponded to average planting dates in California (May 25, 2013). At canopy closure of the rice (the end of the critical period for weed control and time at which weed cover best relates to yield loss), visual weed cover assessments of all major weed species (Echinochloa spp., C. difformis, Leptochloa fusca spp., Schoenoplectus mucronatus, and Ammania spp.) was measured in nine 25 sq. cm quadrats from the weedy (untreated with herbicide) sections in each treatment. At the end of the season, we harvested the same quadrats for fresh and dry biomass and separated them on a per-species basis. The biomass was dried for 72 hours at 65 °C and then weighed.

Two 10 ft by 20 ft areas were harvested from the weedy sections of each treatment and adjusted to 14% moisture. The weed-free sections were also harvested, and adjusted to 14% moisture.

Results
Yields are consistent across treatments when weeds are 100% controlled (non-weedy plots) (Figure 8). However, without weed control, yield in DS-AWD was zero and yields were significantly reduced in WS-AWD and WS-Control (Figure 8).

The weed species prevailing at canopy closure (Figure 5) were: barnyardgrass (Echinochloa crus-galli), which was the primary species in drill-seeded, and ducksalad (Heteranthera spp.), which was the primary species in water-seeded treatments. At harvest, the prevailing weed species were still barnyardgrass (Echinochloa spp.) remains in the drill-seeded. However, ducksalad (Heteranthera spp.) was no longer present in the water-seeded systems (it had completed its life cycle), and had been replaced by Echinochloa spp. as the primary species in water-seeded treatments.

Grasses (Echinochloa spp. and L. fusca) were the main drivers of yield loss both when evaluated at canopy closure and at harvest, across all irrigation systems (Figure 6). In the presence of grasses, sedges and broadleaves do not contribute significantly to yield loss, across all irrigation systems (Figure 7), but may cause significant yield losses when grasses are controlled (Figure 7). Late watergrass (E. phyllopogon) is able to emerge under both aerobic and anaerobic conditions, making it highly competitive regardless of irrigation system. Although smallflower umbrella sedge (C. difformis) emerges at high numbers under flooded conditions, it is not highly competitive against other weed species or rice after emergence.
In these irrigation systems, grasses were primarily responsible for yield loss, outcompeting rice, sedges and broadleaves for resources.

Figure 5. Differences in weed cover between the three irrigation systems at canopy closure (top). Comparative differences between corresponding irrigation treatments at harvest (bottom).

Figure 6. (Left) Rice yield loss as predicted by percent grass cover (open symbols) and percent sedge and broadleaf cover (closed symbols) at canopy closure. As grass cover increases, yield loss increases (open symbols). There is a negative relationship between sedges and broadleaves and yield loss, indicating that in a multi-species system, grasses are the better competitors. (Right) Rice yield loss as predicted by grass biomass (open symbols) and sedge and broadleaf biomass (closed symbols) at harvest. As grass biomass increases, yield loss increases (open symbols). There is not a corresponding predictive relationship between sedge/broadleaf biomass and rice yield loss (closed symbols).
Figure 7. (Left) Percent grass cover is negatively correlated to sedge and broadleaf cover (combined), indicating that grasses are highly competitive against other species in this system. (Right) Percent grass cover is positively correlated to grass biomass at harvest, indicating that grass cover at canopy closure predicts grass biomass at harvest.

Figure 8. Yields (kg ha\(^{-1}\)) across three irrigation systems (DS-AWD, WS-Control, WS-AWD). Letters (a,b,c) indicate significant differences at p=0.05 (Tukey means separations test).

**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**

Grower response to resistance testing services increased this year with a total of 43 samples submitted. Response was highest in smallflower umbrella sedge, as concern over propanil-resistance has increased. Two new cases of resistance were reported this year: resistance to ACCase inhibitors in sprangletop (*L. fusca* spp. *fascicularis*) and resistance to propanil in late watergrass (*E. phyllopogon*) (Figure 9). Investigation into mechanisms of resistance and new alternative herbicide options are currently underway. Current suggestions to control clomazone- and ACCase inhibitor resistant sprangletop is thiobencarb (Bolero, Abolish). Clincher (cyhalofop) can still be used to control clomazone-resistant sprangletop, except in cases of multiple-resistance to both herbicides, and Cerano (clomazone) can be used to control ACCase inhibitor resistant sprangletop. The current recommendation for late watergrass is a clean-up application of Abolish + Regiment (1.5 qt + 0.53 oz) at the 5 lsr.
4.2. Field testing of herbicides

Two off-station sites with ALS-inhibitor resistant sedges and multiple-resistant late watergrass were planted this year, to test herbicide combinations intended for resistant sites. The site in Yuba County will be discussed in this report (Table 11). The soil at the site was fast-draining red soil. The grower used a pump and a well to maintain water in his fields, and the water level was not consistent through the season (there were many periods of drainage).

The products tested this year included GWN-10380 (benzobicylon + halosulfuron), which has shown promise in controlling resistant sedges in the greenhouse. Other herbicide combinations tested included Shark H2O with a variety of follow-up herbicides, for control of ALS- and propanil-resistant sedges. GWN-10380 (7.5 lb/a) alone did not control late watergrass (less than 50% control across all timings). It had excellent control of ricefield bulrush when applied at the 5 lsr or earlier. Control of smallflower umbrella sedge decreased when applied later than the 1 lsr (80% or less when applied at the 3 lsr or later). Ducksalad and arrowhead control were consistently low (less than 60% across all timings). The combination of Cerano (DOS) followed by GWN-10380 at 1 lsr (12lb fb. 7.5lb) increased control of watergrass to 98%. The combination caused some phytotoxicity (7% stand reduction), but it was not significantly greater than phytotoxicity usually caused by Cerano alone (approximately 20%). GWN-10380 followed by Regiment + UAN + NIS at the 1-2 tiller stage (7.5lb fb. 0.4oz + 2.0% + 0.2% v/v) also increased late watergrass and ducksalad control. However, there may have been escapes, as control decreased to 73% by 60 days after seeding.

Shark H2O was less effective at controlling sedges than GWN-10380. The best sedge control was in the treatment where it was followed by SuperWham + COC (6 qts +1.25% v/v) at the 1-2 tiller stage (75% of ricefield bulrush). It was more effective than Granite GR at controlling
ALS-resistant sedges, indicating that it is currently a viable option (as benzbicyclon is not yet on the market).

The highest-yielding treatment was Granite GR fb. SuperWham + Grandstand + COC (15lb fb. 6qt + 8oz + 1.25% v/v) with 9086 lb/a. Cerano fb. GWN-10380 (12lb fb. 7.5lb) was the next highest yielding, with 8866 lb/a.
Table 11. Continuous Flood Trial (Resistant Site)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Rate</th>
<th>Prod./a 1st</th>
<th>Prod./a 2nd</th>
<th>1st 2nd</th>
<th>14 DAT</th>
<th>7 DAT</th>
<th>14 DAT</th>
<th>12-May (20 DAS)</th>
<th>1-Jun (60 DAS)</th>
<th>21-Jun (80 DAS)</th>
<th>11-Sep</th>
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<tr>
<td>Untreated</td>
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<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
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<td>---</td>
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<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Cerano fb. GWN-10380</td>
<td>673 lb. 250+52.5</td>
<td>7.5oz fb. 250+52.5</td>
<td>1 lsr</td>
<td>2-May</td>
<td>0 0 0 0 0 0 0 0 0 0 0 0 0</td>
<td>24 0 0 0 0 0 0 0 0 0 0 0 0 0</td>
<td>41 4 8 4 0 0 0 0 0 0 0 0 0 0</td>
<td>3 5 4 3 5 4 3 5 4 3 5 4 3 5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shark H2O fb. SuperWham + COC</td>
<td>210 lb. 7.5oz fb. 6726</td>
<td>2-3 lsr</td>
<td>2-May</td>
<td>0 0 0 0 0 0 0 0 0 0 0 0 0</td>
<td>75 0 0 0 0 0 0 0 0 0 0 0 0 0</td>
<td>56 4 2 4 2 4 2 4 2 4 2 4 2 4</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Granite GR fb. SuperWham + Grandstand + COC</td>
<td>40 lb. 210 lb. 6726</td>
<td>1 lsr</td>
<td>1-2 tiller</td>
<td>7-May</td>
<td>0 0 0 0 0 0 0 0 0 0 0 0 0</td>
<td>56 0 0 0 0 0 0 0 0 0 0 0 0 0</td>
<td>46 3 5 3 5 3 5 3 5 3 5 3 5 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GWN-9796</td>
<td>250</td>
<td>7.5oz fb. 250</td>
<td>1 lsr</td>
<td>2-May</td>
<td>0 0 0 0 0 0 0 0 0 0 0 0 0</td>
<td>4 4 4 4 4 4 4 4 4 4 4 4 4 4</td>
<td>4 4 4 4 4 4 4 4 4 4 4 4 4 4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GWN-9796 + Sandea</td>
<td>250</td>
<td>7.5oz fb. 250</td>
<td>1 lsr</td>
<td>2-May</td>
<td>0 0 0 0 0 0 0 0 0 0 0 0 0</td>
<td>4 4 4 4 4 4 4 4 4 4 4 4 4 4</td>
<td>4 4 4 4 4 4 4 4 4 4 4 4 4 4</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

1. Trial seeded April 22, 2014 with 180 lbs per acre of M206.
2. Trial managed as a continuous flood with water started April 18, 2014.
4. Spray applications made with 20 gallons/acre using 8003 nozzles.
5. Weather conditions on May 2: Air temperature 83°F, Water temperature 82°F, wind 3.5 MPH from the southeast.
6. Liquid applications of GWN-9796 were made with 10 foot boom with nozzles removed.
7. Top dressing: 83lb/a ammonium sulfate + 17b nitrogen acetate.

Project No. RP-1
4.3. Mechanisms of resistance

4.3.a. Multiple-herbicide resistance in *Echinochloa phyllopogon* (Late watergrass)

This study is the continuation of previous years’ work. We hypothesized that herbicide resistance may also be the result of an environmental adaptation to abiotic stresses and not only the result of grower selection by herbicides. Thus, non-target site mechanisms responsible for multiple-herbicide resistance could be part of plant stress response networks. Understanding the relationships between resistance to herbicides and tolerance to specific stresses could suggest new avenues for resistance mitigation and/or opportunities for broad-base enhancement of rice tolerance to stresses and herbicides. Therefore, identifying the genes involved in herbicide resistance mechanisms and investigating how they are linked to abiotic stress tolerance would add to our understanding of how resistance to multiple herbicides may have evolved (and might evolve) in *E. phyllopogon* and other weed species. We previously demonstrated that multiple-herbicide-resistant (R) *E. phyllopogon* populations in CA descend from a single founder introduction subsequently dispersed and selected by repeated thiocarbamate use. Yet, a selection pressure driving the evolution of resistance to quinclorac cannot readily be traced for this species. We hypothesized that the mechanisms conferring herbicide resistance to this R-*E. phyllopogon* biotype could be part of abiotic stress adaptation in its original environment. In previous year’s work we found a possible link between resistance to quinclorac and tolerance to the toxic effects of cyanide associated with submergence-stimulated ethylene production. To further explore this hypothesis, we subjected plants to another abiotic stress (PEG induced drought) and two herbicide treatments (thiobencarb and quinclorac). Gene expression of selected candidate genes representing gene families involved in plant stress responses and resistance to herbicides was studied through qRT-PCR. Preliminary results revealed differences in expression in both resistant (R) and susceptible (S) lines upon herbicide and abiotic stress treatments for several genes. Expression of several genes (CYP81A12, CYP81A21 and CYP72A122) encoding P450 enzymes involved in herbicide metabolism processes, was found to be higher in R plants than in S plants after herbicide and PEG induced drought treatment (Figure 7).
4.3.b. Diagnostic and assessment of levels of resistance to propanil in smallflower umbrella sedge (Cyperus difformis) and ricefield bulrush (Schoenoplectus mucronatus)

This project has been carried out for 2 years and is approaching its termination. Initial steps had already determined the presence of resistance (R) or susceptibility (S) to the photosystem II-inhibiting herbicide propanil (Stam 80) in populations of smallflower umbrella sedge (C. difformis) and ricefield bulrush (S. mucronatus) collected in rice fields throughout California’s Northern Sacramento Valley.

4.3.c. Whole-plant dose-response experiments in the presence of the synergist carbaryl in smallflower umbrella sedge (C. difformis)

Screening was performed with propanil at field rate (4.48 kg a.i./ha) to obtain single-seed descents showing either resistance (Cd-R and Sm-R biotypes of smallflower umbrella sedge and ricefield bulrush, respectively) or susceptibility (Cd-S and Sm-S) to propanil within each plant species. Whole-plant dose-response assays using smallflower umbrella sedge lines were carried out in the presence of the carbamate insecticide carbaryl to test for propanil degradation as a mechanism conferring resistance. Carbaryl is known to inhibit the enzyme ary1 acylamidase, which in turn has been shown to degrade propanil in rice and many propanil-resistant weed biotypes. Data from the dose-response experiments were fit to a log-logistic equation and the dose to decrease biomass of different biotypes by 50% (e.g. GR$_{50}$) was calculated and compared using the statistical software SigmaPlot (figure 11 and table 12, below).
As can be seen, results indicated that propanil degradation by aryl acylamidase is, as expected, important in rice cv. M-206 and also propanil-S smallflower umbrella sedge, given the lower GR50S calculated in the presence of carbaryl (a known aryl acylamidase inhibitor). Nonetheless, the same was not the case for Cd-R, whose GR50 was not affected by the presence of carbaryl, therefore demonstrating that propanil metabolism by the enzyme aryl acylamidase is not involved as a mechanism conferring resistance in these plants.

4.3.d Whole-plant dose-response experiments using propanil and the insecticide malathion in smallflower umbrella sedge (C. difformis)
As seen above, the insecticide carbaryl did not synergize propanil against propanil-R smallflower umbrella sedge, indicating that propanil metabolism by the enzyme aryl acylamidase is not implicated as the mechanism of resistance in *C. difformis*. However, the organophosphate insecticide malathion has also been shown to synergize propanil against propanil-R biotypes of many weedy grasses due to its inhibition of P450 monoxygenases and many esterases. P450s can participate in conversions of the parent molecule, whereas esterases play the role of detoxifying propanil’s major metabolite, 3,4-dichloroaniline.

In order to test for possible synergism between malathion and propanil onto propanil-R smallflower biotypes, an experiment was performed following a design similar to the one used for determining the effects of carbaryl. Rice cv. M-206 was again employed as a model plant for propanil degradation. Propanil was sprayed at 8 rates, which varied according to the biotype tested; that is, Cd-S received propanil at rates ranging from 0.14 to 17.92 kg a.i./ha (0.03x to 8x of the field rates), whereas Cd-R and rice received propanil at rates ranging from 1.12 to 143.36 kg a.i./ha (0.25x to 32x). When present, malathion was sprayed at a single rate (1 kg a.i./ha) one day prior to propanil. Fresh aboveground biomass was harvested 15 days after propanil spraying, and the experiment was repeated once for consistency. Figure 12 depicts propanil-R and –S plants 3 days after propanil spraying at a discriminant rate (2.24 kg a.i./ha, which translates to 0.5x).

![Figure 12: Effects of propanil at 2.24 kg a.i./ha (0.5x of the field rate) with or without the addition of malathion onto propanil-S and –R smallflower umbrella sedge, 3 days after propanil spraying. Interestingly, malathion increased propanil damage onto propanil-R plants but no synergism was noticed between propanil and malathion onto propanil-S nor rice plants.](image)

Data were subjected to regression analysis and a log-logistic equation was fit to the data using the statistical software SigmaPlot. Figure 13 presents the curves obtained following this analysis, and meaningful parameters obtained from the regression analysis can be seen on table 13.
As can be seen above, malathion synergized propanil against propanil-R smallflower, but not against propanil-S or rice plants. This is shown by the large decrease in the Cd-R biotype’s $GR_{50}$ in the presence of malathion, which led to an overall decrease in the resistance to susceptible ratio (R/S). It was not possible to perform non-linear regression analysis in rice since the loss of biomass did not reach meaningful values (i.e. did not cross the 80% or 50% marks so parameters could not be calculated). These results differ sharply from the ones obtained following carbaryl use, and indicate that propanil metabolism in propanil-R (Cd-R) smallflower umbrella sedge is at least partially responsible for the plant’s ability to survive propanil applications. It is noteworthy,
however, that even in the presence of malathion, the resistance level of Cd-R is still much greater than Cd-S’s, indicating another mechanism is also responsible for propanil resistance. As will be shown later, a mutation at propanil’s target-site – and partial loss of affinity between propanil and its target-site - explains the resistance to propanil found even when malathion is used.

4.3.e. Whole-plant dose-response experiments in the presence of the synergists carbaryl and malathion in ricefield bulrush (S. mucronatus)

Following the same overall procedures depicted above, focus was given to determine whether or not the propanil resistance mechanism in ricefield bulrush could be related to propanil metabolism. Therefore we tested rather propanil metabolism by aryl acylamidase enzymes (which are blocked by the insecticide carbaryl and are responsible for propanil tolerance in rice and multiple other propanil-R weedy grasses) or P450s and esterases (inhibited by malathion) plays a major role in this resistance case. In order to test for possible synergism between the insecticides and propanil onto propanil-R ricefield bulrush plants (e.g. the Sm-R biotype), an experiment was performed following a design similar to the one used for determining the effects of carbaryl and malathion, with the exception that an additional treatment consisting of a mix of malathion and carbaryl was added. Propanil was sprayed at 8 rates, which varied according to the biotype; that is, propanil-S (Sm-S) bulrush received propanil at rates ranging from 0.07 to 8.96 kg a.i./ha (0.015x to 2x of the field rates), whereas Sm-R received propanil at rates ranging from 0.28 to 35.84 kg a.i./ha (0.06x to 8x). When present, the insecticides were sprayed one day prior to propanil; malathion was sprayed at 1 kg a.i./ha and carbaryl at 6 kg a.i./ha. Fresh aboveground biomass was harvested 15 days after propanil spraying, and the experiment was repeated for consistency. Figure 14 depicts propanil-R and –S plants at harvest day (15 days after propanil spraying).

Figure 14. Propanil-R (top) and –S ricefield bulrush plants treated with propanil at the indicated fractions of the field rate (1x equals 4.48 kg a.i/ha).
Data were subjected to regression analysis and a log-logistic equation was fit to the data using the statistical software SigmaPlot. Table 14 presents meaningful parameters obtained from the non-linear regression analysis.

Table 14. GR50 and R/S values calculated for propanil-R (Sm-R) and -S (Sm-S) ricefield bulrush biotypes, with or without the addition of the insecticides malathion and carbaryl.

<table>
<thead>
<tr>
<th>Biotype</th>
<th>Treatment</th>
<th>GR50 (kg a.i./ha)</th>
<th>R/S</th>
<th>GR50 (kg a.i./ha)</th>
<th>R/S</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1st Run</td>
<td></td>
<td>2nd Run</td>
<td></td>
</tr>
<tr>
<td>Sm-R</td>
<td>Propanil Only</td>
<td>0.77 ± 0.21</td>
<td>5.13</td>
<td>1.69 ± 0.57</td>
<td>7.95</td>
</tr>
<tr>
<td>Sm-S</td>
<td></td>
<td>0.15 ± 0.07</td>
<td></td>
<td>0.21 ± 0.07</td>
<td></td>
</tr>
<tr>
<td>Sm-R</td>
<td>Propanil + Malathon</td>
<td>0.55 ± 0.19</td>
<td>2.75</td>
<td>0.76 ± 0.13</td>
<td>3.10</td>
</tr>
<tr>
<td>Sm-S</td>
<td></td>
<td>0.20 ± 0.03</td>
<td></td>
<td>0.24 ± 0.04</td>
<td></td>
</tr>
<tr>
<td>Sm-R</td>
<td>Propanil + Carbaryl</td>
<td>1.10 ± 0.29</td>
<td>18.33</td>
<td>0.83 ± 0.15</td>
<td>5.68</td>
</tr>
<tr>
<td>Sm-S</td>
<td></td>
<td>0.06 ± 0.01</td>
<td></td>
<td>0.14 ± 0.01</td>
<td></td>
</tr>
<tr>
<td>Sm-R</td>
<td>Propanil + Carbaryl+ Malathon</td>
<td>0.59 ± 0.13</td>
<td>4.91</td>
<td>1.08 ± 0.26</td>
<td>6.84</td>
</tr>
<tr>
<td>Sm-S</td>
<td></td>
<td>0.12 ± 0.02</td>
<td></td>
<td>0.15 ± 0.04</td>
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</tr>
</tbody>
</table>

Similarly to the results obtained with smallflower umbrella sedge, propanil-R ricefield bulrush biomass was affected by malathion (i.e. malathion synergized propanil against Sm-R) but not by carbaryl. The same did not hold true for Sm-S, which resembles Cd-S in which its biomass is decreased when carbaryl is sprayed prior to propanil, but not malathion. However, the GR50 of Sm-R plants treated with malathion dropped to values that are still much greater than Sm-S’s, indicating another mechanism could be present in this plants.

4.3.f. Preliminary findings on Resistance of *Leptochloa fusca* spp. *fasicularis* (sprangletop) to clomazone and ACCCase inhibitors

Two subspecies of sprangletop (*Leptochloa fusca* spp. *fasicularis* and *Leptochloa fusca* spp. *uninervia*) are native to California. Both are common to dry-seeded systems or systems where the water level has been allowed to recede (early drain). Preliminary surveys indicate that there are differences between the two subspecies in their distribution: *spp. fusca* is spread throughout rice fields, and *spp. uninervia* appears closer to field edges. Only a few herbicides are available to control sprangletop in California. The two active ingredients most widely used are clomazone (commercial names Command, Cerano, Bombard) and cyhalofop-buty1 (Clincher). Clomazone is a DXP synthase inhibitor, and cyhalofop-buty1 is an ACC-ase inhibitor. Reports of herbicide resistance have been noted in other parts of the world in related *Leptochloa* species, but this is the first reported instance in *Leptochloa fusca*. Resistance has not yet been
documented in the related species *L. fusca* spp. *uninervia* (Mexican sprangletop), also found in California rice.

In the past two years, we received grower field-collected samples that were tested for resistance (2012 and 2013) to these two active ingredients. We confirmed independent populations with resistance to clomazone and cyhalofop-butyl, but have no confirmed cases of multiple-resistance. All samples tested and confirmed resistant are from the spp. *fusca*, not spp. *uninervia*. Preliminary results indicate that resistance to cyhalofop-butyl also confers cross-resistance to quizalofop, but not to clethodim (also ACC-ase inhibitors).

**Materials and Methods**

Seeds from four populations of *L. fusca* spp. *fasicularis* (bearded sprangletop) were collected from different fields in Butte County, CA, in 2012 and 2013. Populations were initially screened for resistance and then accessions with high resistance were selected for further study. Greenhouse experiments for whole plant bioassays were conducted at the Rice Experiment Station, in Biggs, CA in 2013 and 2014.

Seeds were wet-chilled at 15°C for one week, and then planted in 4-inch pots in Yolo clay loam (fine-silty, mixed, nonacid, thermic Typic Xerorthents, 1.7% organic matter). After germination, plants were thinned to 5 plants per pot. Clethodim, cyhalofop and quizalofop were applied using a cabinet track sprayer with an 8001 flat-fan even-spray nozzle (DeVries Manufacturing, Hollandale, MN) to deliver 187 L ha⁻¹ a 248 kPa pressure when plants were at the 1-2 leaf stage. Clethodim was applied at 0, 26.3, 52.5, 105.1, 192.7, 280.2, 560.5 and 1121 g ai ha⁻¹, cyhalofop was applied at 0, 67.7, 156.3, 271, 302.2, 333.5, 667, 1334 g ai ha⁻¹, and quizalofop was applied at 0, 9.6, 19.3, 38.5, 65.5, 92.5, 185 and 277.4 ai ha⁻¹. Plants were flooded 48 h after treatment to 10 cm above the soil. Clomazone was applied into the water at 673 g ai ha⁻¹, and 1345 g ai ha⁻¹ when plants were at the 1-2 leaf stage. A flood was maintained at 10 cm above the soil for the duration of the experiment. Each experiment had one known susceptible biotype and one presumed resistant biotype. The ACCase-herbicides’ experiment was repeated, and each run had two replications of each treatment-biotype combination.

Aboveground shoots were harvested 20 days after treatment (DAT) and fresh weight was measured. Fresh biomass was placed in a dryer at 40°C for 72 hours, or until weight stabilized, and dry weight was measured.

The average maximum temperature in the greenhouse was 37°C and the average low temperature ranged from 22°C (May, 2014) to 24°C (July 2014). Natural sunlight was supplemented by high-pressure sodium lamps yielding 400-600 mol m⁻² sec⁻¹ photosynthetic photon flux density. The photoperiod was 16 h.

Data was analyzed using nonlinear regression in SigmaPlot (Systat Software, San Jose, CA).
Results
Resistance to clomazone and ACCase inhibitors has been confirmed in *Leptochloa fusca* spp. *fascicularis* (bearded sprangletop) in California rice (Figure 15, Table 15). Resistance selected by cyhalofop use confers cross-resistance to quizalofop but not to clethodim (Figure 15). Preliminary evidence suggests that the mechanism of resistance to the cyhalofop and quizalofop is due to a target-site alteration (Figure 16). The mechanism of resistance to clomazone remains to be elucidated, but is suspected to be metabolic. Since Clincher resistance is target-site, growers should use herbicides with a different mode of action, such as Bolero/Abolish (thiobencarb), and benzobicyclon; Cerano (clomazone) can also be an option in the absence of multiple-resistance to this herbicide (although anecdotal references suggest this actually happens). Cerano-resistant sprangletop should be controlled by Bolero/Abolish (thiobencarb), and benzobicyclon; Clincher (cyhalofop) can also be an option in the absence of multiple-resistance to this herbicide (although anecdotal references suggest this actually happens).

![Figure 15](image1.png)

**Figure 15** Dose responses to cyhalofop (1), quizalofop (2) and clethodim (3) of cyhalofop-resistant (R) and -susceptible (S) biotypes. For all experiments, the R biotype tested is RI1, and the S biotype tested is F(S).

<table>
<thead>
<tr>
<th>Clomazone (g ai ha⁻¹)</th>
<th>673</th>
<th>1345</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent Dry Weight Control (% ± s.e.)</td>
<td>S: 100 ± 0</td>
<td>100 ± 0</td>
</tr>
<tr>
<td></td>
<td>R: 35 ± 9</td>
<td>39 ± 10</td>
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</tbody>
</table>

**Table 15.** Percent control (± s.e.) compared to susceptible biotype of dry weight (per pot) of aboveground shoot at 20 Days After Treatment (DAT) with clomazone.

![Figure 16](image2.png)

**Figure 16.** Comparison of partial sequences of the ACCase gene in susceptible (F(S)) and resistant (RI1) biotypes. The resistant biotype has a substitution at Trp2027Cys: a nucleotide change from guanine to thymine (TGG to TGT) at the third position of the codon encoding the aminoacid tryptophan (Trp), which translates to a change from tryptophan to cysteine (Cys).
4.3.g. Preliminary findings on Resistance of *Echinochloa phyllopogon* (late watergrass) to propanil

Propanil-resistance in watergrass (*Echinochloa* spp. complex) appeared evident in several grower-submitted samples from 2013. Reports from growers of decreased efficacy of propanil on watergrass have also been circulating for a few years. Thus, a preliminary dose-response using three populations (with known resistance profiles to other herbicides) was conducted to assess the presence of resistance in these populations.

**Methods**

Seeds were wet-chilled at 15°C for two weeks, and then planted in 4-inch pots in Yolo clay loam (fine-silty, mixed, nonacid, thermic Typic Xerorthents, 1.7% organic matter) and topped with 1 inch of sterilized soil. The pots were placed in enough water to allow moisture to be absorbed (water level was kept below the soil surface). Seed was pre-germinated in an incubator and transplanted into pots (5 plants each). Treatments were applied using a cabinet track sprayer with an 8001 flat-fan even-spray nozzle (DeVries Manufacturing, Hollandale, MN) to deliver 187 L ha⁻¹ a 248 kPa and 20 gallons/acre when plants were at the 2 leaf stage. Treatments were 8 rates of SuperWham + COC. The pots were flooded to 4 inches above the soil surface 48 hours after spraying.

Each treatment-biotype combination was replicated 6 times (6 pots containing 5 plants each). The average irradiance (at plant height) was between approximately 400 µmol s⁻¹ m⁻² (morning) to approximately 1000 µmol s⁻¹ m⁻² (midday). Daylight hours were fixed at 16 hours of light and 8 hours of dark using metal halide lights (to simulate rice-growing season conditions).

Surviving plants were harvested by cutting the stem at 0.5cm above the soil surface, at 20 days after application. The number of plants and the fresh weight of the aboveground biomass were recorded. Plants were then dried at 30°C for a week and their dry weight was also recorded. Percent control was calculated in reference to untreated checks, for both fresh and dry weights.

**Results**

At the field rate of propanil (3363 g ai/ha), Biotype 3 showed resistance to propanil (R/S ratio of 3.4), which indicates the presence of low-level resistance in this population. The population was not resistant to other herbicides, indicating that propanil-resistance has evolved in populations that are not multiple-resistant. Herbicides that successfully controlled this biotype were Abolish (thiobencarb), Prowl (pendamethalin) and Tide (clethodim). Biotype 2 was not resistant to propanil, but was resistant to thiobencarb. It was successfully controlled by Prowl (pendamethalin) and Tide (clethodim) (Note: data not shown).
Figure 17. Regression curves depicting loss of fresh aboveground biomass of 3 biotypes of late watergrass (*Echinochloa phyllopogon*) 20 days after propanil application.

Table 16. ED50’s and R/S ratios for three biotypes of late watergrass (*Echinochloa phyllopogon*) 20 days after propanil applications. Biotypes 1 and 2 are susceptible to propanil at the field rate (3363 g ai/ha), whereas biotype 3 shows low-level resistance at the field rate (3.4 R/S ratio).

<table>
<thead>
<tr>
<th>Biotype</th>
<th>ED50±95% CI (g/ha)</th>
<th>R/S</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>809.3</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>612</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>2051</td>
<td>3.4 (P&lt;0.05)</td>
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**Objective 5: Investigations into new weed threats to California rice production.**

5.1. Sprangletop subspecies
There is no new information to report on the ecology or distribution of the two sprangletop (*L. fusca*) subspecies (spp. *fascicularis* and spp. *uninervia*) found in California rice. All resistant samples given for testing by growers in California through 2013 have been identified as spp. *fascicularis*. In 2014, work continues to identify grower samples as one of the two subspecies.

5.2. Sedges
Two species of sedge that were previously found only on the edges of rice fields were found in the middle of fields for the second year. They have been identified as *Cyperus iria* (ricefield flatsedge) and *Cyperus flavicomus* (whiteedge flatsedge) (Figure 18). Neither are California natives (according to Calflora). *C. iria* is a widespread weed of rice worldwide (including in the Southern USA), but *C. flavicomus* is not currently considered a weed of rice. Both weeds will be monitored in rice-growing counties in California.
PUBLICATIONS OR REPORTS


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: continuously flooded rice, partially flooded rice (pin-point) and drill seeded rice. Some of the compounds used this year included the 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 (GWN-10380) provided good broad-spectrum control, especially when paired with Clincher, Cerano or Granite. Phytotoxicity was generally low. Two new formulations of League MVP by Valent Company are under development to increase control of late watergrass and ricefield bulrush. RiceEdge by RiceCo LLC is a newly available herbicide (formulation of propanil+halosulfuron) which can be used in place of SuperWham as a clean-up spray. OR-009 is a new surfactant by Oro-Agri which increases the efficacy of SuperWham at our susceptible fields.

Early results from germination, emergence and growth experiments for late watergrass, smallflower umbrella sedge, and now, ricefield bulrush, indicate that we continue to move forward in developing a model that will eventually be available to farmers in the field. Work on alternative irrigation management systems continues to enhance our understanding of weed population dynamics across rice systems in California, and prepare us for an uncertain future in terms of water availability.

Propanil-resistant smallflower umbrella sedge and ricefield bulrush are an increasing problem in California rice fields. Smallflower umbrella sedge resistance levels to propanil are extremely high. Through the continued investigation of alternative management methods as well as new herbicide options, we will continue to develop practices that can be used on these sedges. Currently, Shark H2O and Bolero are good alternative for both sedges, as is League MVP, although at current rates this last product may be less efficacious on ALS-inhibitor-resistant sedges. Propanil-resistant watergrass has also been confirmed. Currently, a clean-up spray of a tank-mix of Abolish + Regiment or use of the stale-seedbed technique are the recommended options for both multiple-resistant and propanil-resistant biotypes. Clomazone-resistant and ACCase-inhibitor resistant sprangletop have also been confirmed, and there have been anecdotal reports of multiple-resistance. Bolero/Abolish should be used to control multiple-resistant biotypes. In biotypes that are only clomazone-resistant, Clincher and Bolero/Abolish are good options. Cerano and Bolero/Abolish can be used to control biotypes that are only resistant to ACCase-inhibitors.

Results from our UC Davis laboratory illustrate our progress in identifying mechanisms of herbicide resistance in late watergrass, smallflower umbrella sedge, ricefield bulrush, and sprangletop. Once mechanisms have been identified, we will be better able to design rational programs to manage herbicide resistant weeds.
As always, both our field and lab program seeks to assist California rice growers in their critical weed control issues of preventing and managing herbicide-resistant weeds, achieving economic and timely broad-spectrum control and complying with personal and environmental safety requirements.