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PROJECT TITLE: Weed Management in Rice

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OBJECTIVES OF PROPOSED RESEARCH:

1. Optimize and improve the efficacy of herbicide applied alone, in tank mixes, or/and in sequential treatments. Develop herbicide alternatives and programs that are efficacious, simple, adoptable, and cost effective.
2. Test new compounds that address critical weed control needs in rice cropping systems to ensure they are efficacious, compatible, and useful for California rice production.
3. Develop management alternatives by integrating agronomical and cultural practices to improve weed control, minimize costs, and reduces environmental impacts.
4. Study mechanism of herbicide resistance in weeds and identify programs to manage resistant biotypes.
5. Provide diagnosis services to growers and PCA to confirm cross/multiple resistance in rice fields, and mapping the spread of resistance in California rice production areas.

SUMMARY OF 2019 RESEARCH:

The UC Rice Weed Research Program at the Rice Experiment Station, Biggs, CA seeks to assist California rice growers in achieving their weed control and herbicide resistant management goals. This year's program focuses on the performance and evaluation of new herbicides (including herbicides under development) in mixtures and/or sequential combinations with existing herbicides primarily for continuously-flooded rice system. Highlights of this year's program include new techniques to reduce weed pressures as well as study the efficacy of new herbicides incorporated into existing weed control programs. This year research program include advanced testing of two new herbicides, Pyraclonil and Loyant for weed control in rice. Pyraclonil is a PPO inhibitor whereas Loyant is hormonal-type herbicides. We also studied the effect of clomazone applied at different rate and timing on rice and weed control. Research also was conducted to optimize Butte herbicide for grass and weed control in rice. Moreover, we studied the response of rice to tank-mix of propanil with three fungicides to ensure no negative effects of the combinations on rice. Furthermore, we continue our research to develop drill-seeded rice system for California that will help to manage herbicide resistant weeds.

Almost all of our research focus in 2019 was on continuous flood system which has been historically the most common rice growing system in California as this system promotes suppression of most competitive rice weeds such as barnyardgrass, watergrass, and sprangletop. In this system, a water depth of 4 inches is maintained throughout the season after seeding rice into a flooded field. When late post-emergence foliar applications are needed, water depth is lowered to expose about two-thirds of weed foliage to the herbicide spray, but fields are never completely drained. This year, our planting was delayed for two weeks from normal planting date in late May, however, our harvest was conducted at the normal date in late October. Therefore, the 2019 cropping season was shorter by two weeks.

This year the predominant weed species were late watergrass, ducksalad, ricefield bulrush, smallflower umbrella sedge, followed by barnyardgrass, monochoria, waterhyssop, redstem and sprangletop. All weeds evaluated in our program are susceptible to herbicides registered for California rice.

Objective 1. Optimize and improve the efficacy of herbicide applied alone, in tank mixes, or/and in sequential treatments. Develop herbicide alternatives and programs that are efficacious, simple, adoptable, and cost effective.

Due to variations in growing and irrigation methods utilized by farmers around the state of California, we continue to test herbicides in different settings, including continuous flood, pinpoint flood, and dry/drill-seeding with flush irrigation. Experiments were conducted at the Rice Experiment Station (RES) in Butte County at two fields. The continuous flood, pine-point and the efficacy of Loyant and pyraclonil herbicide experiments were planted on June 13, whereas new herbicide testing experiments and direct seeded rice studies were planted on June 15. The seeding rate was 120 lb/A. Continuously flooded plots were seeded into flooded fields, and water levels were maintained at approximately 4 inches throughout the season. The level of water, however, was lowered for certain late season herbicide treatment and water level brought back 48 h after treatment. Water was drained at about a month before harvest, to facilitate machine harvest.

In pinpoint study, plots were also flooded at seeding, but water was drained at a specific point to allow for foliar herbicide application. For the drill-seeded experiment, seeds were drilled into the soil, and the field was then flushed repeatedly to establish the rice. After the rice reached the 3-4 leaf stage, the fields were flooded with 4-6 inches of water.

Weed control and rice injury were rated using 0 to 100 scale where 0 = no injury and 100 = mortality. Weed control and rice injury rating were conducted 20, 40, and 60 days after seeding (DAS). In all studies, weed control was also rated by species. All herbicide applications were made with a CO_2-pressurized (30 PSI) hand-held sprayer equipped with a ten-foot boom and 8003 nozzles, calibrated to apply 20 gallons/acre. Applications with solid formulations were made by evenly broadcasting the product over the plots.

In this report, the trade name of herbicides was used and the herbicide rates appear as amounts of formulated product; a cross-reference between brands and active ingredients is presented in Table 1.

Continuous Flood System

For this system, several into-the-water herbicide products are available for controlling weeds in continuously flooded rice that include Bolero, Butte, Cerano, Granite GR and SC, League MVP, Shark H2O, and propanil. These herbicides can be applied early to provide good to excellent control of labelled (target) weeds. As they vary in the spectrum of weed control, it is sometimes useful to combine two of these herbicides in a program to expand the spectrum weed control.

a. <u>Optimizing Butte-Based Herbicide Programs</u>

This is the second year that Butte® has been available to California rice growers. Butte® is a granular mixture of benzobicyclon and halosulfuron active ingredients developed by Gowan Company. The benzobicyclon component of Butte® adds a new mode of action (HPPD-inhibitor) to the herbicide portfolio for water-seeded rice in California and is meant to provide control for broadleaf weeds, grasses and sedges. The other component of Butte is halosulfuron, an ALS-inhibiting herbicide. Previous studies suggest that Butte® provides good broad spectrum weed control, however, there is great need to consider using Butte in combination with other herbicide such as Clincher, Cerano, Granite, propanil, and Regiment to specifically improve grass weed control. This year weed control efficacy of Butte was tested in programs followed by Regiment, Granite GR, Granite SC, and SuperWham mixed with Grandstand CA. The combination of Butte® followed by other herbicides has provided good weed control results this field season (Table 2).

Butte applied at 13 lb/A followed by into-the-water application of Granite GR (13 lb/A at 3.5 lsr), a follow-up foliar application Regiment (0.67 oz/A + 5 fl oz/A), Granite SC (2.8 oz/A + 2.5% v/v COC at Mid-tiller) or Grandstand (1 pint/A + 0.25% v/v NIS at full tiller stage of rice) provided exceptional control of all weeds (Table 2) except the control of smallflower sedge by Butte follow-up with grandstand or Regiment where smallflower sedge control was below 90% . The choice of the appropriate follow-up application or an inclusion of a granular herbicide (Granite GR) may largely depend on the weed population pressure and/or resistance status of the weeds in the field. Among all treatments, the lowest herbicide cost ($118) was with Butte follow up by Grandstand.

b. <u>Effect of Cerano applied at different rates and timings on rice and weed control</u>

Leather's method is used in water-seeded systems by draining the field within the first few days after seeding and reflooding once the crop has established shallow roots, roughly 1 week after seeding. This allows for good crop establishment and rooting, but also allows weeds the opportunity to become highly competitive with adequate moisture for germination and low water depths for emergence and rapid development. Many growers use Cerano (clomazone), a micro encapsulated granule, to control sprangletop, barnyardgrass by way of carotenoid biosynthesis which causes bleaching symptoms. Cerano has a day of seeding application timing with a 14-day water holding period once applied to a field. However, if growers are using a Leather's method, it is not possible to use Cerano because of the labeled water holding requirements. In this study Cerano was applied at the day of seeding and well as after a Leather's method, ~7DAS, to determine if there was adequate weed control as well as any crop damage.

Cerano 5MEG was applied at 8, 10. And 12 lb/A at day of seeding or after leathering. To control broadleaf weeds and sedges, a treatment of Granite GR at 3 lb/A at 5 leaf stage and SuperWham at 4 qt/A were applied to all treatments. In general weed control was greater was greater when Cerano was applied at day of seeding than after leathering. In addition, the increase in Cerano rates from 8 to 12 lb/A did not result in significant improvement in weed control. It seems that rates of 8 to 10 lb/A is sufficient to provide adequate grass control (Table 3). In general, Cerano applied after leathering accentuated injury on rice.

While rice bleaching is similar or less when Cerano applied after leathering, rice stand reduction and stunting were greater when Cerano applied after Leathering (Table 3). In general, rice yield was greater when Cerano applied at day of seeding than after leathering. In addition, gave similar yield with all Cerano treatments when herbicide was applied at day of seeding (Table 4). However, yield decreased as the rate increased when Cerano was applied after Leathering.

c. Evaluating compatibility of tank mixing Propanil and Fungicides on weed control and crop injury

Fungicides may be used to control diseases such as kernel bunt in rice. Growers may try to tank mix fungicides with propanil to control weeds and also diseases, however, there is a concern that such mixture may cause injury to rice and change weed response to propanil. The objective of this project is to understand rice response and weed control when propanil applied in tank mixes with different fungicides. Herbicide treatments were applied as listed in the table below, with Cerano 5 MEG herbicide applied at day of seeding (DOS), and additional herbicide (H)-fungicide (F) combinations applications at early tillering (ET). Each treatment listed was replicated 4 times, once per block in 4 separate randomized complete blocks, with 2 untreated control (UTC) plots in each block. The treatments are listed in the table below.

Trtmt #	Type	Treatment	Rate	Timing
1	H	Cerano	12 lb/ac	DOS
	H	SuperWham	6 qt/ac	ET
	F	Stratego	19 fl oz/ac	ET
2	H	Cerano	12 lb/ac	DOS
	H	Stam	7.5 lb/ac	ET
	F	Stratego	19 fl oz/ac	ET
3	H	Cerano	12 lb/ac	DOS
	H	SuperWham	6 qt/ac	ET
	F	Quadris	15.5 fl oz/ac	ET
4	H	Cerano	12 lb/ac	DOS
	H	Stam	7.5 lb/ac	ET
	H	Quadris	15.5 fl oz/ac	ET
5	H	Cerano	12 lb/ac	DOS
	F	Tilt	10 fl oz/ac	ET
	H	SuperWham	6 qt/ac	ET
6	H	Cerano	12 lb/ac	DOS
	H	Stam	7.5 lb/ac	ET
	F	Tilt	10 fl oz/ac	ET
7	UTC			

The crop was visually evaluated for chlorosis, bleaching, stunting, and stand reduction at 15, 30, 45, and 60 days after application (DAA). Weed control was also visually evaluated at the same time intervals; key weed species included watergrass, sprangletop, rice field bulrush, smallflower umbrella sedge, ducksalad, Monochloria, water hyssop, and redstem. Crop injury and weed control results from each treatment group were averaged across all replicates

Table 5 showed the average crop injury and weed control ratings for all treatment combinations. Throughout the observation period there was little to no Monochoria present, so ratings were not listed for this weed. Stand reduction was rated based on weed competition and was not representative of actual crop loss. At 15 days after treatment, there was some bleaching, chlorosis, and stunting for all treatment plots with the exception of the UTC plots. watergrass, sprangletop, bulrush, and redstem were well controlled at this time point (Table 5). At 40 days after treatment, the bleaching, chlorosis and stunting in all treatments was reduced to 0 and remained low for the remainder of the trial (Table 5). Control of bulrush and smallflower decreased at this time; water hyssop appeared, but remained at or above 90% control for the duration of the trial. Some chlorosis on the bulrush tips were observed as well as considerable necrosis of ducksalad present in most plots. Rice yields were not affected by any herbicide fungicide tank mixes.

d. <u>Response of rice algal assemblage to fertilizer and chemical application: implications for the early algal bloom management</u>

California rice production is challenged by nuisance algae in the beginning of the growing season. Rapid, early formation of algal mats at the time of flooding can prevent the establishment of newly emerged rice seedlings. The conventional method for controlling algae, i.e. the aerial application of copper sulfate, fails to consistently provide satisfactory results perhaps because the method of application (aerial) is suboptimal, selection of algae species in the flooded rice that have innate tolerance to the chemistry, or any combination thereof. Two bucket experiments (ten chemicals) and one field study (five chemicals) were conducted and ten chemicals with possible algaecide activity were tested. The chemicals were: test including Cutrine-Plus (a.i. copper ethanolamine complex), Cutrine-Ultra (a.i. copper ethanolamine complex), liquid peroxide (a.i. hydrogen peroxide), Goal 2XL (a.i. oxyfluorfen), Ronstar (Oxydiazone), Algimycin (a.i. chelated copper), Algimicyn+ AMP surfactant, liquid peroxide+AMP , zinc sulfate and elemental copper (blue stone). In the bucket study, algae were collected from the field and inoculated to the buckets one week before algaecide application. Chlorophyll a content of water, fresh and dry biomass of algae were measured every second day for 14 days. The results showed that chelated copper (Algimicyn) had the highest algae control (86%), followed by Protox herbicides (Goal2XL and Ronstar) (70%). Blue stone copper, Cutrine-Plus and Cutrine-Ultra controlled algae similarly (50-70%). Hydrogen peroxide only controlled algae by 50% and its efficacy dropped dramatically five days after treatment. Zinc sulfate was only effective at 1 DAT and algae recovered rapidly after that. The field experiment was conducted in the 3x3 ft plots. Fertilizer were minimally incorporated to the soil to stimulate uniform growth of algae. All the chemicals, except Goal 2XL, were applied at the time of the algae bloom (two days after flooding the field). Goal 2XL was applied three days before flooding to the soil surface as pre-emergence. Visual observations were taken every second day on the algae coverage at the water surface and scored from 0 (no algae coverage) to 100% (full coverage of the water surface). The maximum algae control (96%) was observed with the pre-emergence application of Goal 2XL while zinc sulfate gave the lowest algae control (21%) at 24 hours after algaecide application. Cutrine-Plus (70%), Cutrine-Ultra (60%) and liquid peroxide (60%) provided similar level of algae control while outperforming copper sulfate application (47%). The fastest algae recovery was observed in Cutrine-Ultra and Cutrine-Plus treated plots while the algae coverage in other treatments remained low even eight days after algaecide treatment. Rice was able to establish in all the algaecide treatments except Goal 2XL which severely damaged the rice crop. All the tested algaecides have the potential to reduce the early bloom of algae, however, further investigation is needed to determine the optimal time of application and their effects on rice.

Objective 2. Test new compounds that address critical weed control issues in California rice cropping systems to ensure that they are efficacious compatible, and useful for California rice production.

Thirteen separate studies were conducted to evaluate different new formulations and herbicide active ingredients in continuous flood system. Summary of the results are below:

a. Weed control and rice safety with pyraclonil

Pyraclonil, a PPO-inhibitor, is a granular formulation currently under development for weed control in CA rice by Nichino America, Inc. PPO-inhibitors are important for weed control in rice because so far we do not have any confirm weed resistance to this mode of action, and pyraclonil should provide good control for broadleaf weeds, grasses. Previous studies demonstrated that pyraclonil would be best used as part of a comprehensive weed control program. Pyraclonil is less effective on sprangletop, smallflower sedge and rice bulrush. This year pyraclonil was applied as a part of programs which included Butte, Cerano, Bolero, Regiment, Granite GR, SuperWham and Loyant (table 6). Results showed outstanding weed control including smallflower umbrella sedge and broadleaf weeds when pyraclonil applied in combination Bolero UltraMax, Butte, and Loyant. Additionally, rice did not show signs of injury from pyraclonil.

A separate study was conducted to evaluate California rice variety to pyraclonil. Pyraclonil was applied at day of seeding on M105, M205, M206, M209, S102 and Koshihikari rice. There were no varietal response to pyraclonil. All rice varieties showed good tolerance to pyraclonil. Another study was conducted to evaluate different formulations of pyraclonil. The granule forms tested exhibited excellent weed control and they are commercially quality granule. In addition, two other studies we conducted to determine the optimum application time of pyraclonil. Results showed the best and effective application timing is at day of seeding. Our research showed that pyraclonil is a very promising herbicide for weed control in California rice, most importantly for controlling and managing a variety of herbicide-resistant weeds in California rice fields.


Pyraclonil alone


Pyraclonil + Cerano


Pyraclonil + Regiment

b. <u>Weed control and rice safety with Loyant herbicide program</u>

Loyant (florpyrauxifen-benzyl) is being developed by Corteva and is a post-emergence herbicide in liquid formulation meant to control broadleaf weeds, grasses and sedges. Loyant is an auxin type herbicide, representing a mode of action that currently does not have any known resistant weeds in CA rice. This year two separate studies was conducted to evaluate Loyant in programs with Clincher, Granite, RebelEX, Cerano, Bolero, and Butte. When applied alone, this herbicide provides good weed control but seems to be the most effective as an addition to existing programs. For example, applications with Loyant plus Granite, Loyant plus Butte, and Loyant plus Bolero gave near complete weed control (Table 7). Loyant herbicide is safe on rice and provided nearly complete control of all weeds present in the field with no or slight initial crop injury. Our research showed Loyant is promising tool for weed control in CA rice. It will contribute for weed control in general but it will be excellent addition to control herbicide resistant water grass and smallflower sedges.


Non-treated control


Butte followed by Loyant


Bolero followed by Loyant


RebelEx followed by Loyant

c. We have conducted three separate studies to evaluate a new grass herbicide from FMC. It is mainly a grass control herbicide with little activity on broadleaf and sedges. It has a wider window of application compare to other grass control herbicides. In addition, it has novel mode of action that can be extremely helpful to manage herbicide resistant grasses. This year, the herbicide continue to show excellent grass control with great safety on rice. We have evaluated time of application, formulation and herbicide partners. The herbicide has excellent safety on rice with outstanding grass control. We will continue our research to determine the optimum time for herbicide application. We have tested the herbicide on California rice varieties where excellent tolerance was observed with all varieties.

d. New herbicide formulations. Several new clomazone formulations were tested for weed control and crop safety in rice. The use pattern and rates are similar for Cerano. In general, research showed that crop safety and weed control of new formulations are similar to Cerano. The purpose of this study is to have more than one company to market clomazone for California rice with the goal to have more competitions that may reduce cost of Cerano for growers. We have also tested new formulations for Butte herbicide. These formulations look promising.

Objective 3. Develop management alternatives by integrating agronomical and cultural practices to improve weed control, minimize costs, and reduces environmental impacts.

a. <u>Effect of water and soil burial depth on emergence and growth of weedy rice</u>
This research is associated with the management and prevention of California weedy rice. This summer we conducted field experiments to observe the timing and conditions for emergence of various weedy rice types 1, 2, 3 and 5. The experiment began June 9th and lasted for 28 days and was set at the Davis field site where weedy rice research is currently being conducted. Thirty seeds of each type were planted in separate pots for a semi-structured environment conducive for collecting data. On June 9th seeds were planted at random depths immediately followed by flooding of the field. It is important to note that weedy rice had been previously planted in this field during 2018, separated by weedy rice type. Emergence was counted daily; air and water temperature were measured hourly for the duration of the experiment. Results show that all weedy rice types emerged from the soil within 14 days of flooding; the majority of seeds emerged from the top 1 cm of the soil (Figure 1). Type 3, the weed suspected of existing in California for the longest period of time, had the highest rate of emergence.

In addition to the field studies, our research continues to determine temperature and water potential conditions best for germination of weedy rice under controlled conditions. We have tested temperatures with 10 degree increments from 50 to 104 degree and water potentials with -0.2 Mpa increments from 0 Mpa (deionized water) to -0.8 Mpa for types 1, 2, 3, 5 as well as M206 for comparison. In this experiment water potential is meant to mimic soil moisture similar to field conditions. Results thus far infer that at 85 degree, there is not a large difference in germination patterns between -0.2, -0.4, and -0.6 Mpa for all weedy types as well as M206, but there are obvious differences between 0Mpa and -0.8 Mpa. However, at 60 degree M206 and Type 2 had best overall germination, regardless of water potential, with type 5 doing well with 0 Mpa, and types 1 and 3 appearing to lack a tolerance for colder temperatures regardless of water potential.

The germination results will be combined with the data from an emergence experiment conducted during the 2019 field season to create predictive models to determine the timing of weedy rice emergence. The field experiment mentioned here will be used to validate the accuracy of the models created from these two experiments. The field study here will be repeated during the 2020 field season and germination experiments should reach completion by the fall of 2020.

b. Adopting drill seeded rice for weed control

Drill seeding rice is practiced widely in the US South, yet is virtually absent in California. Common practice is to drill rice to no more than 1”, and flush-irrigate until all herbicides have been applied, whereupon a 1 to 2” flood is established. The zone of maximal weed germination and emergence is typically up to 1” depth as well, therefore the crop and weeds emerge at the same time, and weed management options are limited to rice-safe herbicides. Our objective for the 2019 season was to continue our drill-seeding protocols, focusing on water management and a herbicide program centering on a postplant-preemergent application of glyphosate. Results from 2018 were promising, thus this year we repeated the protocols for year-over-year data. Our field setup consisted of a split-split- plot experimental design, with main plots of drilling depth (1 inch and 2 inches), subplots of cultivars M-206 and M-209, and sub-subplots of four herbicide protocols. The herbicide program followed the protocol in the table below:

2019 Drill seed treatments

Trt#	Treatment	Crop timing
1	• Glyphosate • Bispyribac (Regiment CA) + Dyne-amic • Cyhalofop (Clincher CA) + COC	• First leaf, just at surface • 3 leaf • 3.5 leaf (sprangletop cleanup)
2	• Glyphosate • Bispyribac (Regiment CA) + Dyne-amic + Pendimethalin (Prowl H2O) • Cyhalofop (Clincher CA) + COC	• First leaf, just at surface • 3 leaf • 3.5 leaf (sprangletop cleanup)
3	• Glyphosate • Bispyribac (Regiment CA) + Dyne-amic + Clomazone (Command) • Cyhalofop (Clincher CA) + COC	• First leaf, just at surface • 3 leaf • 3.5 leaf (sprangletop cleanup)
4	UNTREATED	

Weather was a major factor this season, as multiple late spring storms delayed planting by about a month. In addition, the rains caused germination of most *Echinochloa* grasses prior beginning our fieldwork. This effectively eliminated *Echinochloa* weed pressure in our field over the season.

Cultivars at both seeding depths reached emergence at 6 days after planting, with rice from the 1”-depth plots emerged about ½”, and the 2”-depth plots just breaking the surface. Glyphosate was applied on all treated plots at 6 days after planting, and injury to the rice was limited to first-leaf tip dieback, which the plants grew out of and developed normally. Stunting due to glyphosate injury was not observed.

As watergrass was largely nonpresent over the season, later-germinating bearded sprangletop was able to compete more effectively with rice and sedges. Glyphosate alone reduced bearded sprangletop by more than 50% in all treated plots, with the remainder of the herbicide program ensuring a weed-free season (Table below). Sedges were nonpresent except in trivial numbers in untreated plots, as flush-irrigation disfavors aquatics.

Bearded sprangletop plants/ ft^2

Treatment	22dap (Glyphosate only)				38dap			
	1”		2”		1”		2"	
	M-206	M-209	M-206	M-209	M-206	M-209	M-206	M-209
t1	2	.8	.7	3.6	0	0	0	0
t2	1.4	.3	.2	.9	0	0	0	0
t3	2.8	2.1	.7	.9	0	0	0	0
t4 (UTC)	29.8	22.7	28.2	26	0	0	0	0

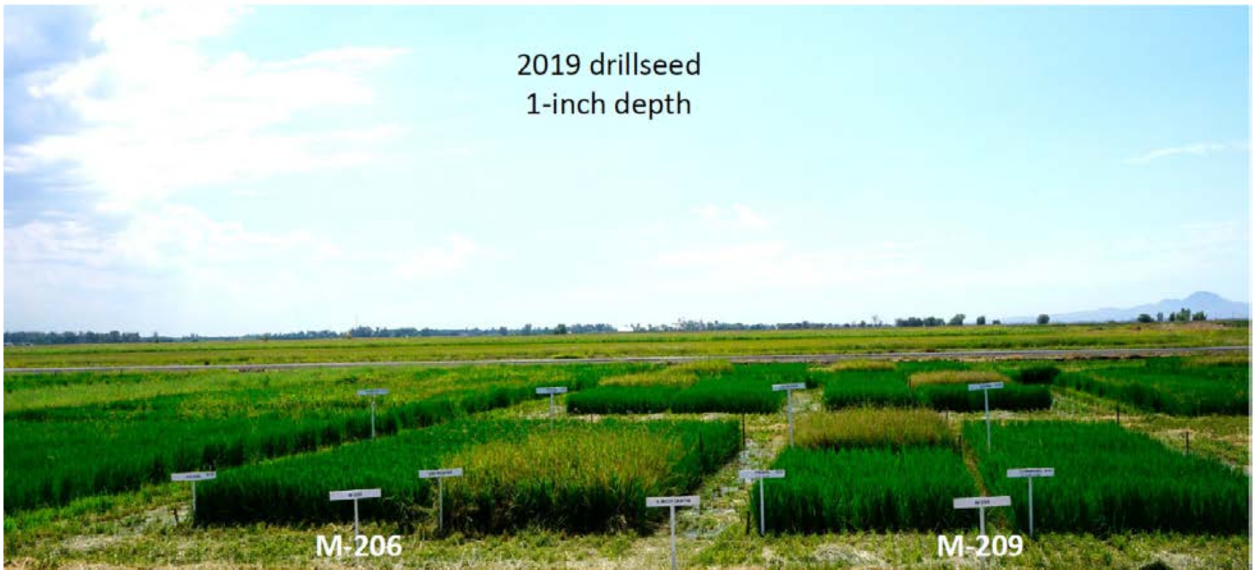
As weed pressure was severely reduced, untreated plots were able to support weak crop stands this year. Below-average daytime temperatures and a shorter season contributed to reduced yields over 2018. M-209 in particular suffered as the later-heading cultivar did not experience a full season for adequate grain filling. Yields for treated plots for either cultivar were no different across seeding depths or across the three herbicide protocols used (Table below).

2018

cultivar	Average yields (lb/ac) across treatments (excluding UTC)	
	1”	2”
M-206	9080	9130
M-209	10700	10875

2019

cultivar	Average yields (lb/ac) across treatments (excluding UTC)	
	1”	2”
M-206	8230	8630
M-209	8280	8000



c. Sprangletop control by adjusting water depth in rice fields

Bearded sprangletop is a problematic weed in California rice production. Flooding was thought to suppress bearded sprangletop germination, emergence, and growth; however, after many years of continuous rice production, anecdotal evidence suggests that some bearded sprangletop biotypes can tolerate flood stress. The objective of this research was to determine the response of two bearded sprangletop biotypes [clomazone -susceptible (S) and -resistant (R)] to flooding depth. A study was conducted at the California Rice Experiment Station in Biggs, CA to test the flooding tolerance of two bearded sprangletop biotypes against 2, 4, and 8 inches continuous flooding depths. Plant emergence, plant height, panicles per plant, seed per panicle, 100 seed weight, and seed per plant data were collected. At the 2 inches flood depth, neither biotype was controlled, and the R-biotype had 27% more emergence, produced 78% more panicles per plant, and 29% more seed per plant than the S-biotype. With a 4 inches flood, only the R-biotype survived flooding and produced significantly more panicles per plant and seed per plant than any other treatment-biotype combination tested. There was no emergence of bearded sprangletop in the 8 inches flood depth of either biotype. Continuous flooding can still be used as a management tool to control bearded sprangletop, however, the depth of flooding appears to limit emergence of S- biotypes at 2 and 4 inches for R- biotypes and completely inhibits growth for both biotypes at 8 inches.

Developed adaptation mechanisms for tolerating an anoxic environment has been documented to be related to better tolerating oxidative stress. Some of the species reported to be tolerant to flooding also have been documented to be resistant to herbicides via developing a more efficient oxidative stress pathway. The most recent example of this type of herbicide resistance is the R-biotype of bearded sprangletop used in this study. This biotype metabolizes clomazone via P450 oxidation to less toxic metabolites. The results of this study indicate that clomazone-resistant bearded sprangletop is more likely to spread throughout the Sacramento Valley because they can tolerate a standard flood and survive applications of the commonly used herbicide. It is evident from this study and other research to control bearded sprangletop biotypes will require the use of integrated weed management. It is suggested that California rice growers rotate crops if possible, rotate herbicide modes of action often, use weed-free rice seed, and increase flood levels when possible to achieve effective management of bearded sprangletop. Although a direct relationship between flooding tolerance in an anoxic environment and herbicide resistance mechanisms involving oxidative stress efficiency still needs to be established; the present results suggest further research on mechanisms to mitigate oxidative stress in bearded sprangletop.

Objective 4. Study mechanism of herbicide resistance in weeds and identify programs to manage resistant biotypes, provide diagnosis services to growers and PCA to confirm

a. Survey of California rice fields for acetolactate synthase (ALS) resistance/cross resistance in *Cyperus difformis* (smallflower sedge).

Smallflower sedge is a major weed in California rice. Historically, Smallflower sedge was control with ALS-inhibitors, however, extensive use of these herbicides led to development of resistance. In 2019 we expanded our research into ALS-inhibitor cross resistance in smallflower umbrella sedge. Dose-response studies were performed on populations representing six major ALS cross resistance patterns (Table 8). Herbicides used were Londax, Halomax, Regiment, and Granite, at rates up to 12x label rate. Results confirm that most of the resistance is dose-dependent, therefore resistance mechanisms are likely to be non-target site based (Figure 2). Population R18 showed strong survival to all rates of applied herbicides and may have target-site resistance, which if confirmed would be the first known case of smallflower target-site ALS resistance in California.

We are also continuing our research on determining the mechanisms of resistance to each ALS inhibitor in the selfsame representative populations. A genetic study is underway to determine whether alteration to the *ALS* gene may be causing resistance. A greenhouse study is underway to determine whether cytochrome P450 herbicide metabolism is a mechanism of resistance. In the coming months we will conduct studies to measure the metabolic breakdown of each ALS inhibitor *in planta*, and to determine if reduced herbicide uptake or translocation are involved in reducing herbicide efficacy.

b. Survey of California rice fields for clomazone resistance in Breaded Sprangletop

Clomazone Resistant Survey. Out of 21 populations tested, 17 populations were susceptible and four populations (5%) were resistant to clomazone (Table 9). Clomazone caused severe injury symptoms on susceptible (S)-biotype plants within 7 days after treatment (DAT) at both rates used. Symptoms were generally stunting, chlorosis followed by bleaching of leaf tissue, and necrosis. At 3 weeks after treatment (WAT) 100% mortality was reached in all S-populations (Table 9).

All resistant (R)-population plants were slightly injured by clomazone 7 DAT. Injury symptoms were slight chlorosis, stunting, and bleaching of leaf tissue. Plant foliage was stunted but the growing point was not killed. Resistant populations showed slight symptoms after exposure to the 1X rate of clomazone, and greater injury from the 4X rate. However, by 3 WAT, injured leaves recovered, and plants had resumed normal growth. Clomazone-resistant populations 15 and 19 had less biomass when clomazone was not applied compared to the susceptible population, however, the dry weight of resistant populations 2 and 9 were not different from susceptible when no herbicide was applied. The dry weight of resistant populations decreased with increasing clomazone rate, indicating a dose response and possible metabolic resistance. Populations 2, 15, and 19 which had the greatest level of resistance compared to other populations were subjected to a dose response study. R-populations came from different fields in Colusa and Sutter counties in North Central California with different management practices. The locations of these fields suggest that the R-populations may have evolved independently multiple times (Figure 3). R-populations were in fields that had diverse herbicide use histories, however, only few of the herbicides used are labeled for bearded sprangletop control (Table 9). Although clomazone was used in most fields in the study and the growers suspected clomazone resistance, only 5% of the populations tested were resistant to clomazone. The possible reason for the widespread complaints of failure of bearded sprangletop control in CA rice is likely due to late weed emergence timing and mis-timed applications of clomazone.

Dose Response. At low rates, S plants exhibited clomazone symptoms similar to what was described above. The clomazone dose response study established 100% mortality of S-population at a rate of 0.25 times use rate. Clomazone symptoms on R plants were similar to that of the S-population, however, the R-populations were markedly less affected by clomazone compared to the S-population. The rate required to cause high rates of mortality of resistant bearded sprangletop was more than 4X rate. R-population 19 plants exhibited slight bleaching symptoms at rates lower than 1X rate but plants recovered by 3 WAT. R-population 19 plants treated with 1X rate exhibited moderate bleaching symptoms at 7 DAT and at 3 WAT plants were stunted, bleached, and necrotic. R-population 19 plants treated with rates higher than 1X rate displayed similar symptoms with stunting, severe bleaching and chlorosis at 7 DAT but were completely bleached by 14 DAT. At 3 WAT, rates 4X rate and higher caused severe plant necrosis. R-population 15 population plants were less affected by the clomazone compared to R-population 19, R-population 15 showed slight bleaching at rates lower than 1X rate but plants fully recovered by 3 WAT. At 4X rate, R-population 15 plants exhibited moderate bleaching injury at 7 DAT. At 3 WAT, most of the R-population 15 plants had complete plant bleaching and/or necrosis, with a few plants surviving. R-population 2 was the least affected by clomazone with complete mortality not reached until exposed to the 4X use rate. At rates of 4X and lower, R-population 2 plants exhibited slight to moderate bleaching but recovered by 3 WAT. At rates 5X or higher, 7 DAT R-population 2 plants showed severe plant bleaching, with complete plant bleaching at 2 WAT followed by necrosis.

The clomazone GR50 for R-populations 19, 15, and 2 were 1.2, 1.8, and 4.5X rates, respectively, whereas the GR50 for the S-population was 0.11X rate (Figure 4). The established mortality rate of the S-population used in this study was similar to that of the rates causing 50% mortality (GR50) reported for other clomazone-resistant species. The clomazone use rate in California rice production, however, is higher than other production systems of where other clomazone-resistant weeds were reported and could account for the higher levels of resistance found in our study.

This is the first reported case of clomazone-resistant bearded sprangletop worldwide.
In spite of many claims of bearded sprangletop clomazone resistance by CA rice growers, only a few populations were confirmed resistant under controlled conditions. Rather than being solely due to resistance, other factors may be also contributing to clomazone failures on bearded sprangletop in CA. Low levels of resistance are likely due to the recurrent low doses of clomazone in the water by the time bearded sprangletop emerges. The use of clomazone in CA rice production in the future could be beneficial, as there is not widespread resistance, however, it should be used at the appropriate timing and as part of an herbicide program to prevent further development of clomazone resistance.

c. <u>Mechanism of clomazone resistance in breaded sprangletop.</u>

Bearded sprangletop is a problematic weed in California rice production. Bearded sprangletop has been controlled with clomazone in California rice fields since 2004. The continuous use of clomazone and lack of crop rotation in rice fields resulted in resistance to clomazone in several bearded sprangletop populations. The objective of this research was to determine the mechanism of resistance to clomazone in bearded sprangletop populations from California rice fields by investigating clomazone absorption, translocation, and metabolism under controlled environmental conditions in two resistant (R- CRBS1 and CRBS2) and one susceptible (S) populations. Absorption and translocation of ^{14}C-clomazone were similar in R and S. Clomazone metabolism, as determined by inhibition of cytochrome P450 enzymes with malathion and determining clomazone metabolites profile, was different between S and R three days after treatment. Bearded sprangletop pretreated with malathion was 2-fold more sensitive to clomazone than when the same population was treated with clomazone alone, indicating metabolic resistance. An HPLC-MS/MS analysis revealed differences in clomazone metabolism between R and S. Hydroxymethylclomazone was the most abundant metabolite found with three and five-fold more abundant in CRBS1 and CRBS2, respectively, when compared to S plants. R plants accumulated less than half as much 5-ketoclomazone, the known toxic metabolite of clomazone, compared to S plants. This research shows that clomazone is metabolized differently by R and S populations of bearded sprangletop and that P450 monooxidation is likely involved in the mechanism of resistance.

b. <u>Diagnostic and detection of herbicide resistance in Farmers' fields</u>

For seeds collected from 2018 growing season, testing of suspected herbicide resistant weeds was conducted on 157 seed samples. Growers and PCA submitted weed seeds samples including barnyardgrass, early and late watergrass, smallflower umbrella sedges, sprangletop, ricefield bulrush, and redstem. We tested the response of these weed to several herbicides not only to confirm resistance to particular herbicide but also to give growers herbicide options in case they have resistance in their fields. For 2018-19, we have tested 12, 29, 34, 23, 27, 28, and 4 samples of ricefield bulrush, smallflower umbrella sedge, late watergrass, early watergrass, barnyardgrass, breaded sprangletop and redstem. For testing, we have used the following herbicides for each species:

Most of the sample tested showed resistance to at least one herbicide. We had several sample with multiple resistance. We provided each grower with extensive report that include photos of plant response to different herbicides and recommendations to select alternative herbicide to control their herbicide resistant weed. The summary of results is in Table 10.

We will continue to test suspected resistant weed populations provided by growers and PCA. This implies conducting the greenhouse tests during the winter in order to have results available to growers in a timely manner before they have to make decisions on their herbicide program. For each sample received, we will be testing all herbicides that are recommended to control the weed. The protocol is similar to 2018 protocol. Growers/PCA(s) will receive a report that not only show if the weed is resistance to particular herbicide(s) but also provide herbicide alternatives for controlling of this particular biotype. The reporting method to growers allows visual results along with the resistance data. This approach has been well received by the growers and PCA who utilized the service. For 2019, we have already received more than 75 samples.

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GENERAL SUMMARY OF CURRENT YEARS RESULTS

Research was conducted to develop effective weed management programs in three rice cropping systems including continuous flooded rice, partially flooded rice (pinpoint) and drill seeded rice. Testing of herbicide programs in continuous flood, pinpoint, and drilled rice showed no herbicide alone would provide adequate weed control. Weed control program in rice require early herbicide applications such as thibencarb, clomazone, or Butte followed up by postemergence herbicide. The efficacy of these programs would depend on herbicides in the program, time of application and water level. For example, when Butte is used optimum control occurred when Butte applied at day of seeding until 3-leaf stage. Any delay in application can results in poor weed control.

We have expanded our research on pyraclonil, a new herbicide from Nichino America, Inc. A rate, timing, formulations and herbicide partner program of pyraclonil studies in continuously-flooded rice showed that pyraclonil, has excellent activity on grasses, sedges including smallflower umbrella sedge and broadleaf. In addition, pyraclonil provides excellent crop safety when applied at 1 leaf stage of several California rice varieties. We also continue to optimize

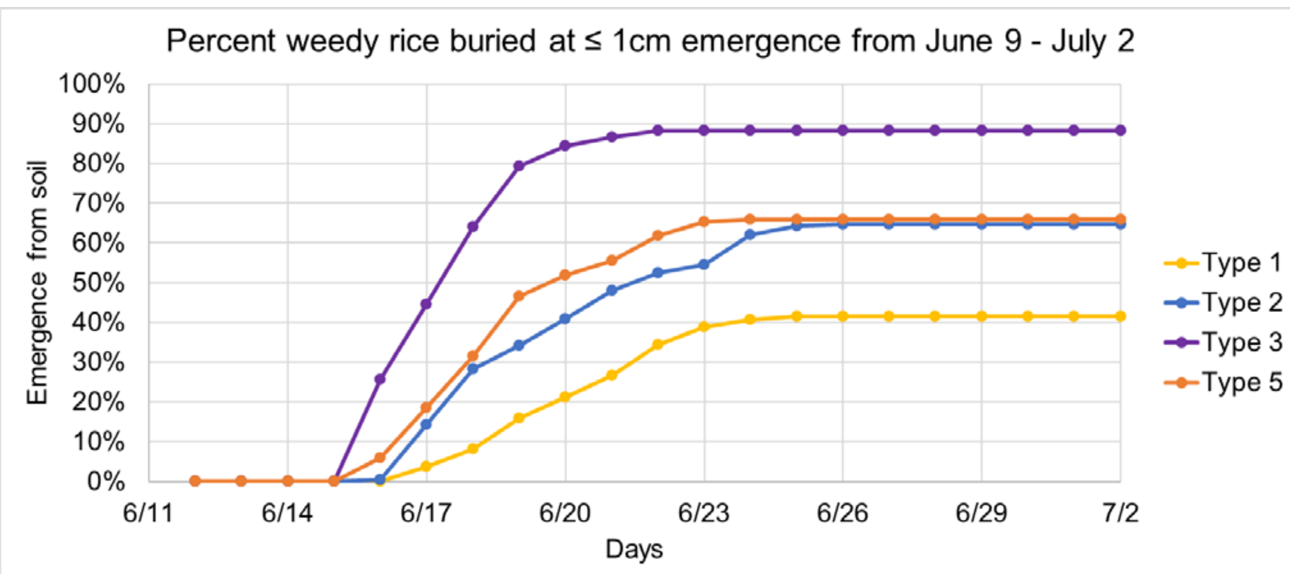
Loyant, a new herbicide that will be available to California growers in near future. Loyant showed excellent postemergence weed control with good safety on rice. Loyant has good activity on barnyardgrass, smallflower sedge and broadleaf weeds. Loyant will be very useful herbicide for a clean-up treatment. However, Loyant alone would not give adequate weed control and therefore it needs to be applied tank mixed with other herbicide. We also continue to work on a new grass herbicide from FMC. It showed very promising results to control most of grasses. Further research is needed to optimize rate and time of applications.

We continue working to optimize weed management in drill-seeded rice. A field study was conducted in which M-206 and M-209 rice were planted at three depths (0.5, 1.5 and 2 inches) and glyphosate was applied just before the first leaf of rice reached the soil surface. Both cultivars and both seeding depths reached emergence at 6 days after planting, with rice from the 1"-depth plots emerged about ½", and the 2"-depth plots just breaking the surface. Glyphosate was applied on all treated plots at 6 DAP, and injury to the rice was limited to first-leaf tip dieback, which the plants grew out of and developed normally. Stunting due to glyphosate injury was not observed. The follow-up herbicide treatments gave a near perfect weed control. The drill seeded rice cropping system also allow us to use pendimethalin herbicide that are not labeled on water seeded system and has a mode of action that help in control herbicide resistant weeds. Our research also showed that drill-seeded rice yield was similar to water seeded rice cropping system.

Our research on the flooding tolerance of two bearded sprangletop biotypes showed that bearded sprangletop has adapted to flooded conditions common in most California continuous flooded rice fields. The depth of flooding appears to limit emergence of clomazone-susceptible biotypes at 1 to 4" for clomazone-resistant biotypes. The results of this study indicate that clomazone-resistant bearded sprangletop is more likely to spread throughout the Sacramento Valley because they can tolerate a standard flood and survive applications of the commonly used herbicide. It is suggested that California rice growers rotate crops if possible, rotate herbicide modes of action often, use weed-free rice seed, and increase flood levels when possible to achieve effective management of bearded sprangletop. Although a direct relationship between flooding tolerance in an anoxic environment and herbicide resistance mechanisms involving oxidative stress efficiency still needs to be established; the present results suggest further research on mechanisms to mitigate oxidative stress in bearded sprangletop.

In 2019, we have tested more than 150 samples of suspected herbicide resistant weed populations that were collected by growers and PCA including barnyardgrass, early and late watergrass, smallflower umbrella sedges, sprangletop, ricefield bulrush, and redstem. Most of the sample tested showed resistance to at least one herbicide. We had several seed samples with multiple resistance. We provided each grower with extensive report that include photos of plant response to different herbicides and recommendations to select alternative herbicide to control their herbicide resistant weed. In 2020, 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, achieve economic and timely broad-spectrum control and comply with personal and environmental safety requirements.

Figure 1. Percent weedy rice emergence for a 21-day period from June 9th through July 2nd. Most weedy types did not emerge after 14 days from flooding the field.



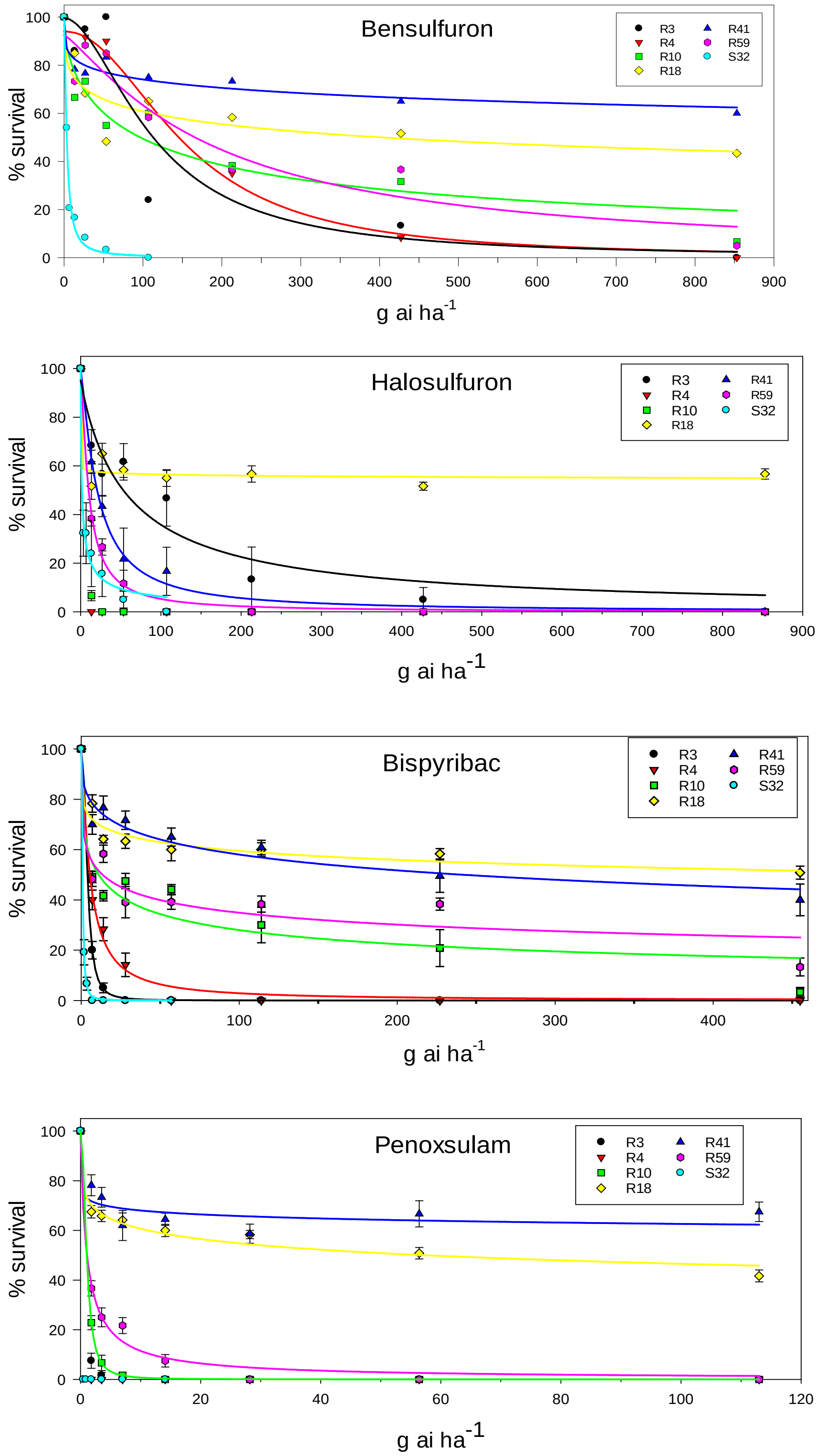


Figure 2. Dose-response results. A: Londax, B: Halomax, C: Regiment, D: Granite

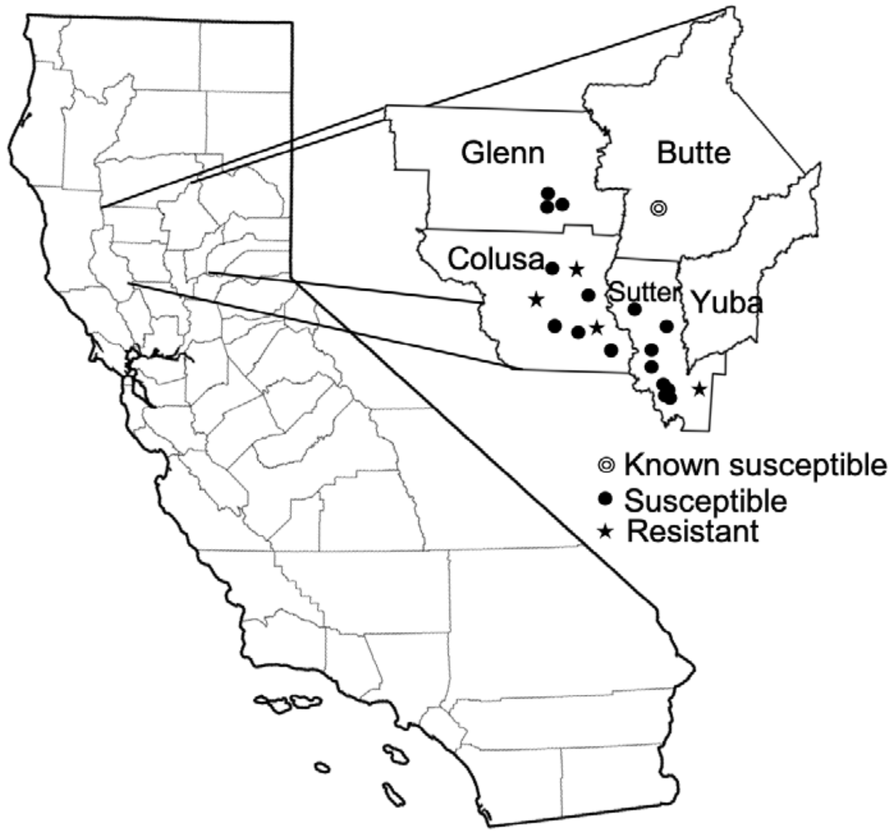


Figure 3. Location of bearded sprangletop populations tested for clomazone resistance. Closed circles indicated a field collection site. Open circles indicated a known susceptible field site. Stars indicate clomazone resistant population site.

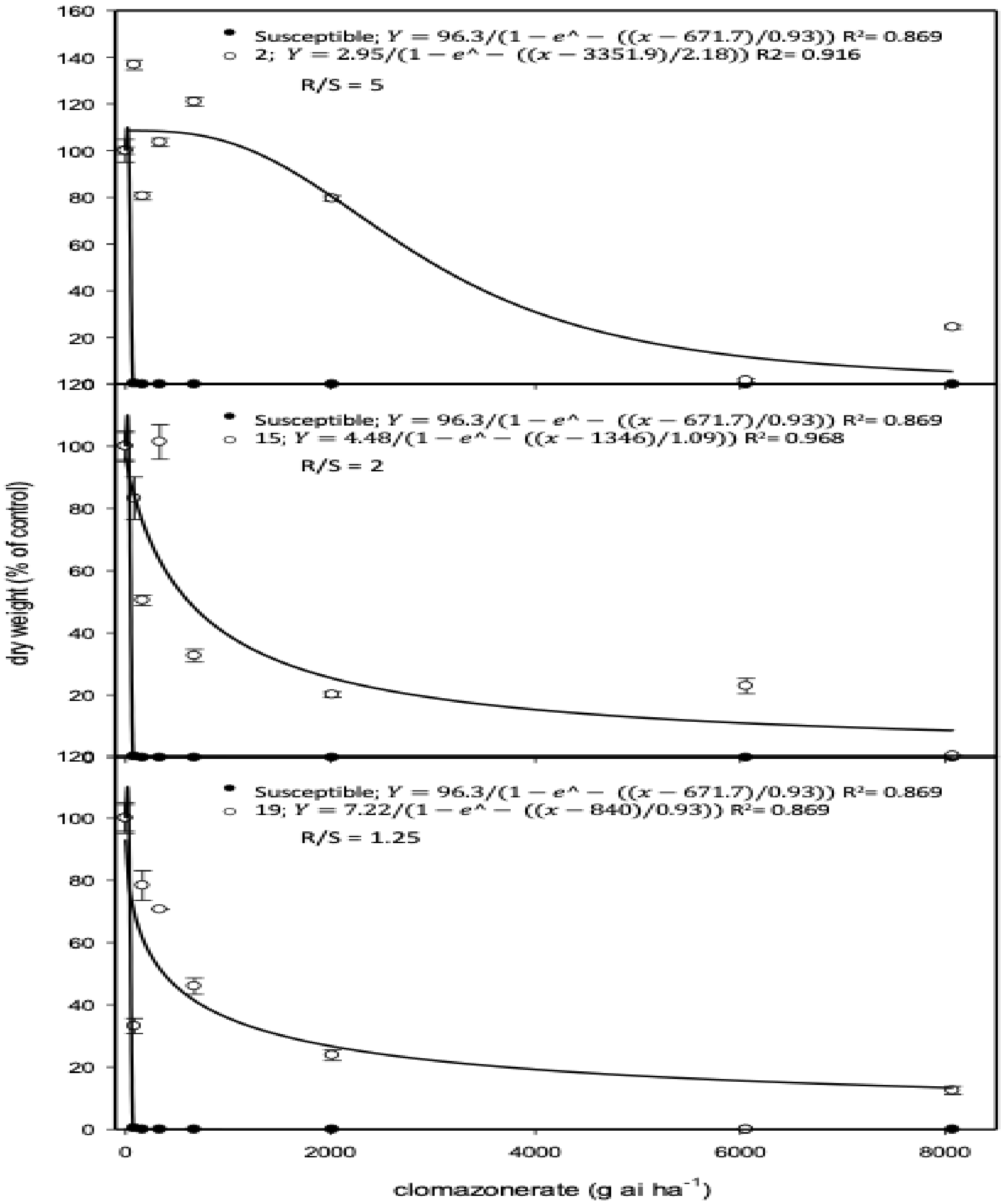


Figure 4. Dry weight of clomazone susceptible (closed circle) and resistant populations (open circle) as affected by different rates of clomazone.

Table 1. Herbicides used and their active ingredient

Herbicide	percentage ai	lb ai/gal
Abolish 8EC (thiobencarb)	84	8.0
Bolero UltraMax (thiobencarb)	15	NA
Butte (benzobicyclon + halosulfuron)	3 + 0.64	NA
Cerano 5 MEG (clomazone)	5	NA
Clincher CA (cyhalofop-butyl)	29.6	2.4
Grandstand (triclopyr)	44.4	3.0
Granite GR (penoxsulam)	0.24	NA
Granite SC (penoxsulam)	24	2.0
Halomax 75 (halosulfuron)	75	NA
Londax (bensulfuron-methyl)	60	NA
Prowl H_2O (pendimethalin)	42.6	3.8
Regiment (bispyribac-sodium)	80	NA
RiceEdge (propanil + halosulfuron)	60 + 0.64	NA
Sandea (halosulfuron)	75	NA
Shark H_2O (carfentrazone)	40	NA
Strada CA (orthosulfamuron)	50	NA
SuperWham! CA (propanil)	41.2	4.0

HERBCIDE PROGRAM	RATE/ACRE	TIMING	WEED CONTROL										CROP INJURY						PRICE
			40 DAS					60 DAS					20 DAS			40 DAS			
			WATERGRASSES	SPRANGLETOP	RICEFIELD BULRUSH	SMALLFLOWER	DUCKSALAD	WATERGRASSES	SPRANGLETOP	RICEFIELD BULRUSH	SMALLFLOWER	DUCKSALAD	STAND REDUCTION	BLEACHING	STUNTING	STAND REDUCTION	BLEACHING	STUNTING	
Butte Regiment + DyneAmic	7.5 lb 0.67 oz + 5 floz	1 LSR Mid-tiller	100	93	-	97	97	100	65	-	88	100	27	0	0	12	0	0	$145
Butte Granite GR	7.5 lb 13 lb	1 LSR 3.5 LSR	100	97	-	98	100	100	70	-	97	100	13	0	0	25	0	0	$158
Butte Granite SC + COC	7.5 lb 2.8 floz + 2.5% v/v	1 LSR Mid-tiller	100	100	-	97	100	100	97	-	92	100	22	0	0	13	0	0	$154
Butte Grandstand CA + NIS	7.5 lb 1 pt + 0.25% v/v	1 LSR Full tiller	100	97	-	90	97	100	98	-	85	100	15	0	0	5	0	0	$118
UNTREATED	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 2. . Butte efficacy as affected herbicide partner.

HERBICIDE PROGRAM	RATE/ACRE	TIMING	WEED CONTROL 40 DAS WATERGRASSES	40 DAS SPRANGLETOP	40 DAS RICEFIELD BULRUSH	40 DAS SMALLFLOWER	40 DAS DUCKSALAD	60 DAS WATERGRASSES	60 DAS SPRANGLETOP	60 DAS RICEFIELD BULRUSH	60 DAS SMALLFLOWER	60 DAS DUCKSALAD	CROP INJURY 20 DAS STAND REDUCTION	20 DAS BLEACHING	20 DAS STUNTING	40 DAS STAND REDUCTION	40 DAS BLEACHING	40 DAS STUNTING	PRICE
Cerano Granite GR SuperWham + Grandstand + COC	8 lb 13 lb 4 qt + 1 pt + % v/v	DOS 5 LSR Full-Tiller	75	100	90	76	100	100	100	98	96	100	8	9	10	13	0	8	$181
Cerano Granite GR SuperWham + Grandstand + COC	10b 13 lb 4 qt + 1 pt + % v/v	DOS 5 LSR Full-Tiller	50	100	90	63	99	100	100	96	88	100	15	6	10	13	0	3	$192
Cerano Granite GR SuperWham + Grandstand + COC	12 lb 13 lb 4 qt + 1 pt + % v/v	DOS 5 LSR Full-Tiller	75	100	75	64	100	100	100	98	90	100	10	34	23	16	0	6	$203
UNTREATED	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cerano Granite GR SuperWham + Grandstand + COC	8 lb 13 lb 4 qt + 1 pt + % v/v	7 DAS 5 LSR Full-Tiller	0	100	95	80	100	100	100	94	85	96	53	0	25	16	0	10	$181
Cerano Granite GR SuperWham + Grandstand + COC	10b 13 lb 4 qt + 1 pt + % v/v	7 DAS 5 LSR Full-Tiller	0	100	94	80	100	100	100	94	84	97	45	0	13	21	0	20	$192
Cerano Granite GR SuperWham + Grandstand + COC	12 lb 13 lb 4 qt + 1 pt + % v/v	7 DAS 5 LSR Full-Tiller	0	100	94	64	100	100	100	73	54	90	80	33	43	48	0	10	$203
UNTREATED	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 3, Weed control and rice injury as affected by Cerano applied at day of seeding and after leathering

Herbicide program	Rate (product per acre)	Timing	Yield lb/A
Cerano Granite GR SuperWham + Grandstand	8 lb 13lb 4 qt + 1 pt	DOS 5 LSR Full Tillering	8,350
Cerano Granite GR SuperWham + Grandstand	10 lb 13lb 4 qt + 1 pt	DOS 5 LSR Full Tillering	7,891
Cerano Granite GR SuperWham + Grandstand	12 lb 13lb 4 qt + 1 pt	DOS 5 LSR Full Tillering	8492
Cerano Granite GR SuperWham + Grandstand	8 lb 13lb 4 qt + 1 pt	DOS 5 LSR Full Tillering	6162
Cerano Granite GR SuperWham + Grandstand	10 lb 13lb 4 qt + 1 pt	DOS 5 LSR Full Tillering	5731
Cerano Granite GR SuperWham + Grandstand	12 lb 13lb 4 qt + 1 pt	DOS 5 LSR Full Tillering	5092
Untreated control			4,507

Table 4 . Rice yield as affected by different rates of Cerano applied at day of seeding and after leathering.

			WEED CONTROL										CROP INJURY						
			40 DAS					60 DAS					20 DAS			40 DAS			
HERBCIDE PROGRAM	RATE/ACRE	TIMING	WATERGRASSES	SPRANGLETOP	RICEFIELD BULRUSH	SMALLFLOWER	DUCKSALAD	WATERGRASSES	SPRANGLETOP	RICEFIELD BULRUSH	SMALLFLOWER	DUCKSALAD	STAND REDUCTION	BLEACHING	STUNTING	STAND REDUCTION	BLEACHING	STUNTING	PRICE* EXCL FUNGICIDES
Cerano SuperWham + Stratego + COC	12 lb 6 qt + 19 floz + 2.5% v/v	DOS Early tiller	100	100	89	98	64	100	100	91	100	80	21	19	14	4	0	0	$140
Cerano Stam + Stratego	12 lb 7.5 lb + 19 floz	DOS Early tiller	100	100	76	98	58	100	100	76	100	79	48	35	50	6	0	0	$159
Cerano SuperWham + Quadris + COC	12 lb 6 qt + 15.5 floz + 2.5% v/v	DOS Early tiller	100	100	90	98	74	100	100	80	100	80	25	23	25	4	0	0	$140
Cerano Stam + Quadris	12 lb 7.5 lb + 15.5 floz	DOS Early tiller	100	100	78	98	76	99	100	83	100	83	16	15	19	5	0	0	$159
Cerano SuperWham + Tilt + COC	12 lb 6 qt + 10 floz + 2.5% v/v	DOS Early tiller	100	100	86	98	76	99	100	84	100	84	48	24	30	1	0	0	$140
Cerano Stam + Tilt	12 lb 7.5 lb + 10 floz	DOS Early tiller	100	100	70	97	69	100	100	66	100	83	45	19	44	6	0	0	$159
UNTREATED	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 5. Rice and control as affected by propanil applied in tank-mix with fungicides.

			WEED CONTROL 40 DAS					WEED CONTROL 60 DAS					CROP INJURY 20 DAS			CROP INJURY 40 DAS			
HERBICIDE PROGRAM	RATE/ACRE	TIMING	WATERGRASSES	SPRANGLETOP	RICEFIELD BULRUSH	SMALLFLOWER	DUCKSALAD	WATERGRASSES	SPRANGLETOP	RICEFIELD BULRUSH	SMALLFLOWER	DUCKSALAD	STAND REDUCTION	BLEACHING	STUNTING	STAND REDUCTION	BLEACHING	STUNTING	PRICE* EXCL. PYRACLONIL
UNTREAED	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pyraclonil SuperWham + COC	14.9 lb 6 qt + 2.5% v/v	DOS 5 LSR	91	74	50	55	100	99	79	45	26	100	46	0	55	21	0	4	$74
Pyraclonil Butte SuperWham + COC	14.9 lb 7.5 lb 6 qt + 2.5% v/v	DOS 1 LSR 5 LSR	98	100	94	99	100	96	100	100	83	100	45	0	43	6	0	1	$168
Cerano Pyraclonil SuperWham + COC	6 lb 14.9 lb 6 qt + 2.5% v/v	DOS 1 LSR 5 LSR	99	99	63	55	100	100	100	61	19	100	24	0	30	1	0	1	$107
Pyraclonil Bolero Ultramax SuperWham + COC	14.9 lb 23.3 lb 6 qt + 2.5% v/v	DOS 1.5 LSR 5 LSR	99	100	100	100	100	94	100	96	100	100	73	0	74	26	0	24	$132
Pyraclonil SuperWham + COC Regiment + DyneAmic	14.9 lb 6 qt + 2.5% v/v 0.8 oz + 5 floz	DOS 5 LSR Early tiller	100	94	64	69	78	100	86	66	54	100	36	0	49	8	0	3	$135
Pyraclonil Granite GR SuperWham + COC	14.9 lb 15 lb 6 qt + 2.5% v/v	DOS 2.5 LSR 5 LSR	100	85	99	100	100	75	66	100	96	100	34	0	29	20	0	11	$148
Pyraclonil SuperWham + COC Loyant + MSO	14.9 lb 6 qt + 2.5% v/v 21.9 floz + 0.5 pt	DOS 5 LSR Mid-tiller	97	91	94	94	100	100	89	98	95	100	25	0	34	3	0	1	$74

Table 6. Efficacy of pyraclonil applied in rice at day of seeding.

HERBICIDE PROGRAM	RATE/ACRE	TIMING	WEED CONTROL										CROP INJURY						PRICE* EXCL. LOYANT
			40 DAS					60 DAS					20 DAS			40 DAS			
			WATERGRASSES	SPRANGLETOP	RICEFIELD BULRUSH	SMALLFLOWER	DUCKSALAD	WATERGRASSES	SPRANGLETOP	RICEFIELD BULRUSH	SMALLFLOWER	DUCKSALAD	STAND REDUCTION	BLEACHING	STUNTING	STAND REDUCTION	BLEACHING	STUNTING	
Clincher + Granite SC + COC Loyant + MSO	15 floz + 2.5 floz + 2.5% v/v 1.33 pt + 0.5 pt	4LS WG 1-Til WG	100	99	100	93	100	100	96	100	95	100	10	0	3	13	0	8	$123
RebelEx Loyant + MSO	20 floz 1.33 pt + 0.5 pt	4LS WG 1-Til WG	100	100	95	83	100	100	98	99	88	100	13	0	3	17	0	7	_
Cerano Loyant + Granite SC + MSO	12 lb 1.33 pt + 2.5 oz + 0.5 pt	DOS 1-Til WG	100	100	88	60	100	100	100	96	68	100	20	3	0	12	0	10	$120
Bolero Loyant + Granite SC + MSO	23.3 lb 1.33 pt + 2.5 oz + 0.5 pt	2 LSR 1-Til WG	100	100	98	93	100	100	100	99	98	100	20	0	0	3	0	3	$112
Butte Loyant + Granite SC + MSO	7.5 lb 1.33 pt + 2.5 oz + 0.5 pt	DOS 1-Til WG	100	100	100	97	100	100	100	100	98	100	92	0	23	55	0	23	$148
Cerano Loyant + Regiment + MSO	12 lb 1.33 pt + 0.67 oz + 0.5 pt	DOS 1-Til WG	100	67	63	47	66	100	67	64	48	67	17	3	7	10	0	7	$117
Butte Granite GR	7.5 lb 15 lb	DOS 3 LSR	100	100	100	100	100	100	100	100	100	100	83	3	23	53	0	30	$168
Butte Granite SC	7.5 lb 2.8 floz	DOS 1-Til Rice	100	99	100	100	100	100	100	100	100	100	85	3	20	47	0	27	$148
UNTREATED	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	$0.0

Table 7. Weed control and rice response to Loyant herbicide applied in combination with other herbicides.

Table 8. ALS cross resistance patterns previously observed, and representative smallflower sedges populations.

Pattern (P.)	**Londax**	**Halomax**	**Regiment**	**Granite**	**Populations**
P.1	R	S	S	S	R4
P.2	R	R	S	S	R3
P.3	R	S	R	S	R10
P.4	R	R	R	S	R59
P.5	R	S	R	R	R41
P.6	R	R	R	R	R18

Table 9. Control of bearded sprangletop as affected by two rates of clomazone 3 weeks after treatment. Within columns, means accompanied by the same letter do not differ according to Tukey's honestly significant difference test with P = 0.05.

Bearded Sprangletop Control		
	Rate (g ai ha^{-1})	
Population	736	2200
	--- % control---	
1	100^{a}	100^{a}
2	37.5^{n}	60^{bc}
3	100^{a}	100^{a}
4	93^{a}	100^{a}
5	100^{a}	100^{a}
6	100^{a}	100^{a}
7	100^{a}	100^{a}
8	100^{a}	100^{a}
9	50^{b}	91^{ab}
10	100^{a}	100^{a}
11	100^{a}	100^{a}
12	100^{a}	100^{a}
13	100^{a}	100^{a}
14	100^{a}	100^{a}
15	45^{b}	50^{c}
16	100^{a}	100^{a}
17	100^{a}	100^{a}
18	100^{a}	100^{a}
19	50^{b}	50^{c}
20	100^{a}	100^{a}
21	100^{a}	100^{a}

Weed	# of samples tested	Abolish/ Bolero	Butte	Cerano	Clincher	Grandstand	Granite	Propanil	Regiment	Shark H2O
Number of samples that express hebicide resistance										
Barnyardgrass	27	-[a]	18	0	12	-	20	-	-	-
Early watergrass	23	0	7	0	22	-	-	15	15	-
Late watergrass	34		1	2	20	-		13	9	-
Sprangletop	28	-	2	4	7	-	-	-	-	-
Smallflower sedges	29	4					23	25	25	12
Ricefield bulrush	12	-	0	-	-	0	1	2	-	0
Redstem	4	-	-	-	-	0	0	0	0	-

[a]- herbicide was not included in the test

Table 10. Summary of 2018 Resistance Testing