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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 in different California rice production systems. 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. 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 2023 RESEARCH:

The UC Rice Weed Research Program at the Rice Experiment Station, Biggs, CA seeks to assist the California rice industry in achieving sustainable weed control through research, demonstration, and other extension efforts. 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. We also are evaluating new formulations of existing rice herbicides, as well as refining full-season herbicide programs featuring common rice herbicides, with an emphasis on flexibility and herbicide rotation. Highlights of this year's program

include studying florpyrauxifen-benzyl (Loyant), pyraclonil (Zembu), Roxy technology, GXP-70101, Prowl H2O, tetflupyrolimet (Dodhylex), saflufenacil, WE2058, and WE2055 for weed control in water seeded rice when applied alone or incorporated into existing weed control programs. In addition, we have conducted research to use clethodim as spot treatment to control weedy rice. Furthermore, we have conducted studies to evaluate tree fruits (prune, peaches, walnut, pistachio, and almond) and vine response to simulated drift rates of GXP-70101, tetflupyrolimet, and benzobicyclon. Moreover, we have developed basic biological information to help managing weeds including weedy rice.

We have developed important data and knowledge to help growers managing weeds. Our program for 2023 year included advanced testing of nine new herbicides, Zembu, Loyant, GXP-70101, Prowl H2O, tetflupyrolimet, Roxy technology, saflufenacil, WE2058, and WE2055. Zembu is a PPO inhibitor, Loyant is auxin-type herbicides, Tetflupyrolimet is a DHODH inhibitor which is a new mode of action not only for rice but also for other crops and Prowl H2O is a long chain lipid biosynthesis inhibitor. Research also was conducted to study the response of Roxy rice to different rates and combinations of ALB 2023 and ALB 2024 herbicides in Roxy cropping system. Additionally, we are at the final stage to develop a thermal model to predict weedy rice emergence and we will publish our model soon. Furthermore, we continue our research to understand watergrass differential response to Loyant and identify the mode of resistance to Loyant. Furthermore, we have elucidated the mechanism of sprangletop resistance to ACCase inhibiting herbicides. Research also we continued to elucidate Prowl H2O damage to rice when applied at early growth stages.

Most of our 2023 weed management research was conducted in 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.

The dominant weed species in 2023 within our water-seeded field were watergrasses, bearded sprangletop, smallflower umbrella sedge and ricefield bulrush. Redstems, arrowheads, ducksalad, and waterhyssop were also observed to a lesser degree. Weed control efficacy of herbicide programs presented primarily reflect the visual ratings (average of three or four replicates) 40 to 60 days after seeding. Rice injury (stand reduction, stunting, chlorosis, and necrosis) after herbicide application have also been noted wherever relevant. Our field was seeded with M-209 at 170 lbs., on May 23, May 31 June 2, 2023. For tetflupyrolimet rice varietal response M-206, M-105, CM-202, M-211, M-209 and L-208 were seeded at 178 lb/A and study was planted on Jun 2, 2023. Rice was harvested on November 1, 2, and 3. Rice was seeded by hand or by airplane in continuously flooded plots with water levels maintained at approximately 4 inches throughout the season. The level of water, however, was lowered for certain late season herbicide treatments and water level brought back 48 h after treatment. Water was drained at about a month before harvest, to facilitate rice harvest. 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. Rice injury (stand reduction, stunting, chlorosis, etc.) was evaluated 20 and 40 DAS. All herbicide applications were made with a CO2-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 hand broadcasting the product over the plots.

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 and pinpoint flood. Experiments were conducted at the Rice Experiment Station (RES) in Butte County at three fields. 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 below.

Herbicides used and their active ingredient

Herbicide	Percentage ai
Bolero UltraMax (thiobencarb)	15
Butte (benzobicyclon + halosulfuron)	3 + 0.64
Cerano 5 MEG (clomazone)	5
Clincher CA (cyhalofop-butyl)	29.6
Grandstand (triclopyr)	44.4
Granite GR (penoxsulam)	0.24
Granite SC (penoxsulam)	24
Prowl H_2O (pendimethalin)	42.6
Regiment (bispyribac-sodium)	80
Sandea (halosulfuron)	75
Shark H_2O (carfentrazone)	40
SuperWham! CA (propanil)	41.2

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.

a. Loyant, florpyrauxifen-benzyl, season-long rice weed management program study.

Loyant is a newly registered herbicide for California rice. The active ingredient is florpyrauxifen-benzyl, an auxin-type herbicide (Group 4). The objective of this study was to evaluate Loyant efficacy as a post-emergence application applied in combination with other herbicides for season-long weed control. Bolero UltraMax (Group 8) at 23.3 lb/A, Cerano 5 MEG (Group 13) at 12 lb/A, and Butte (Group 2&27) at 9 lb/A were applied as base treatments followed by Loyant at 1.33 pt/A alone or in mixtures with other available post-emergent rice herbicides at the four- to five-leaf stage rice. Common and widely used California rice herbicides, SuperWham! CA (Group 5), RebelEX CA (Group 1&2), and Regiment CA (Group 2) were selected as Loyant partners. Loyant was also applied at 1.33 pt/A alone and as a sequential application within 14 days without a base treatment (Table 1 and 2). The specific objective is to evaluate rice injury and weed control at 7, 14, 21, 28, and 42 days after each herbicide application.

Most rice growers rely heavily on complex herbicidal weed control programs to control a mixture of grass, broadleaf, and sedge weeds that are well adapted to the continuously flooded rice system in California. Rice injury from Loyant was minimal and insignificant (Table 3). Loyant alone and as a sequential application provided greater than 95% control over grasses, sedges, and broadleaves (Table 4, 5, and 6). As a post-emergence alone and sequential Loyant application after Bolero UltraMax, Cerano 5 MEG, and Butte, control of smallflower umbrella sedge, ricefield bulrush, ducksalad, and redstem was increased to 100% at 28 DAT. Loyant alone after Cerano 5 MEG did not provide greater than 50% control of the two-sedge species, but in mixtures with SuperWham! CA, RebelEX CA, and Regiment weed control was greater than 90%. Rice yield was greater when Loyant used in most herbicides programs (Table 7). This research showed that Loyant can be integrated into season-long herbicide programs to achieve broad-spectrum control of rice weed species.

Table 1. Base herbicide treatments prior to Loyant applications.

No	Treatment	A.I.	Rate	Unit	Rate	Unit	Timing
1-5	Bolero UltraMax	Thiobencarb	3923	g ai/ha	23.3	lb/A	2 LF
6-10	Cerano 5 MEG	Clomazone	672	g ai/ha	12	lb/A	DOS
11-15	Butte	Benzobicyclon Halosulfuron	302 65	g ai/ha g ai/ha	9	lb/A	DOS
16-18	n/a	-	-	-	-	-	-

Replications: 3, Design: RCBD, Treatment units: Treated Plot, Experimental unit size: 3x6 m.

Table 2. Follow-up Loyant applications.

No	Treatment	A.I.	Rate	Unit	Rate	Unit	Timing
2,7,12	Loyant	Florpyrauxifen-benzyl	39	g ai/ha	1.33	pt/A	4-5 LF
3,8,13	Loyant SuperWham	Florpyrauxifen-benzyl Propanil	39 4800	g ai/ha g ai/ha	1.33 5	pt/A qt/A	4-5 LF 4-5 LF
4,9,14	Loyant RebelEX	Florpyrauxifen-benzyl Penoxsulam Cyhalofop	39 39 280	g ai/ha g ai/ha g ai/ha	1.33 20	pt/A fl oz/A	4-5 LF 4-5 LF
5,10,15	Regiment	Bispyribac-sodium	37.5	g ai/ha	0.67	oz/A	4-5 LF
16	Loyant Loyant	Florpyrauxifen-benzyl Florpyrauxifen-benzyl	39 39	g ai/ha g ai/ha	1.33 1.33	pt/A pt/A	4-5 LF mid-tiller
17	Loyant	Florpyrauxifen-benzyl	39	g ai/ha	1.33	pt/A	4-5 LF
18	untreated check	-	-	-	-	-	-

Replications: 3, Design: RCBD, Treatment units: Treated Plot, Experimental unit size: 3x6 m.

Table 3. Rice response at 7, 14, and 21 days after each application.

TRT	PHY			CHL			STU		
	7	14	21	7	14	21	7	14	21
1	10	0	0	0	0	0	5	10	0
2	10	0	0	0	0	0	5	10	0
3	15	0	0	0	0	0	5	10	0
4	10	0	0	0	0	0	5	10	0
5	10	0	0	0	0	0	10	15	0
6	5	0	0	0	0	0	0	0	0
7	5	0	0	0	0	0	0	0	0
8	10	0	0	0	0	0	0	0	0
9	5	0	0	0	0	0	0	0	0
10	5	0	0	0	0	0	0	3	0
11	15	0	0	0	0	0	0	5	0
12	15	0	0	0	0	0	0	5	0
13	20	0	0	0	0	0	0	5	0
14	15	0	0	0	0	0	0	5	0
15	15	0	0	0	0	0	5	10	0
16	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0

Abbreviations: TRT, Treatments; PHY, general phytotoxicity; CHL, chlorosis; STU, stunting.

Table 4. Weed ground cover control data at 14 DAT.

Treatments	WTG	SPG	BLR	SMF	DKS	RDS
1	12	0	33	16	100	0
2	3	0	0	0	0	0
3	2	0	0	0	0	0
4	3	0	0	0	0	0
5	2	0	0	0	0	0
6	0	0	80	25	100	0
7	0	0	1	0	0	0
8	0	0	2	0	0	0
9	0	0	0	0	0	0
10	0	0	1	0	0	0
11	0	0	0	0	0	33
12	0	0	0	0	0	0
13	0	0	0	0	0	0
14	0	0	0	0	0	0
15	0	0	0	0	0	0
16	0	0	0	0	0	0
17	5	0	0	0	3	0
18	97	5	92	84	100	68

WTG, watergrass; SPG, sprangletop; BLR, bulrush; SMF, smallflower umbrellasedge; DKS, ducksalad; RDS, redstem.

Table 5. Weed ground cover control data at 28 DAT.

Treatments	WTG	SPG	BLR	SMF	DKS	RDS
1	12	0	90	12	100	5
2	3	0	0	0	0	0
3	1	0	0	0	0	0
4	0	0	0	0	0	0
5	0	0	1	0	0	0
6	0	0	100	100	100	5
7	0	0	50	50	5	0
8	0	0	10	5	0	0
9	0	0	1	0	0	0
10	0	0	5	0	0	0
11	0	0	0	0	0	75
12	0	0	0	0	0	0
13	0	0	0	0	0	0
14	0	0	0	0	0	0
15	0	0	0	0	0	0
16	3	1	0	0	0	0
17	5	5	5	4	0	0
18	100	100	100	100	100	100

WTG, watergrass; SPG, sprangletop; BLR, bulrush; SMF, smallflower umbrellasedge; DKS, ducksalad; RDS, redstem.

Table 6. Weed ground cover control data at 42 DAT.

Treatments	WTG	SPG	BLR	SMF	DKS	RDS
1	6	0	50	8	50	0
2	4	0	0	0	0	0
3	4	0	0	0	0	0
4	5	0	0	0	0	0
5	3	0	0	0	0	0
6	0	0	100	75	50	0
7	0	0	28	25	1	0
8	0	0	3	7	0	0
9	0	0	0	0	0	0
10	0	0	8	5	0	0
11	1	0	0	0	0	76
12	0	0	0	0	0	0
13	0	0	0	0	0	0
14	0	0	0	0	0	0
15	0	0	0	0	0	0
16	1	0	0	0	0	0
17	5	5	1	1	0	0
18	100	100	100	100	100	100

WTG, watergrass; SPG, sprangletop; BLR, bulrush; SMF, smallflower umbrellasedge; DKS, ducksalad; RDS, redstem.

Table 7. Rice yield of Loyant treatments at harvest.

Treatments	lb/acre	kg/hectare
1	5402	6056
2	5886	6598
3	6384	7156
4	6493	7278
5	6216	6968
6	4268	4785
7	5900	6614
8	6337	7104
9	6477	7261
10	6614	7414
11	5350	5997
12	5872	6582
13	6536	7327
14	6036	6767
15	6457	7238
16	5236	5870
17	6654	7459
18*	1878	2106

b. Cattail, *Typha latifolia*, control with Loyant in Sacramento-San Joaquin Delta.

Cattail is an aquatic weed that generally infests irrigation and drainage canals, lakes, marshes, ponds, rivers, ditches, and streams. It is a perennial plant growing up to 10 feet tall and is more prevalent as a weed in Europe and North America than in other regions. Cattail has recently become an important weed in drill-seeded rice in the Delta region of California. Loyant, is a new synthetic-auxin type rice herbicide that is newly registered in California. The objective of this research is to study the potential of using Loyant for cattail control. Field research was conducted at two sits at McDonald Tract of Delta region during the 2023 growing season. Treatments were Loyant 1.33 pt/A, Grandstand 1 pt/A, Loyant1.33 pt/A plus Grandstand 1 pt/A, and Loyant 2.66 pt/A, respectively, applied with methylated seed oil at 0.5 pt/A at two growth stages (Table 8). The study was a randomized complete block design with four replicates. Herbicides were applied on 80x80 inches plots to a range of cattails from two to three feet tall up to six feet tall growth stages. Visual cattail injuries were rated at 7, 14, 21, 28, 35, and 42 days after treatments using a scale where 0 means no injury and 100 means plant killed. All Loyant treatments did not cause rice injury (Table 9) and achieved 100% control up to three feet cattail tall (Table 10). However, cattail control was reduced when Loyant applied on 6 ft tall cattails at 14 days after treatment but by 42 days after treatment all cattail plants were dead. This study clearly showed that early foliar applications of Loyant up to three feet tall cattail growth stages would provide excellent control of cattails.

Table 8. Loyant treatments to control cattails in the delta area.

Treat. No	Treatment Description	Rate	Rate Unit	Alt Rate	Alt Unit	Appl. Method	Appl. Timing
1	Loyant MSO	39	g ai/ha	1.33 0.5	pt/a	POST	0-3 ft tall
2	Loyant MSO	39	g ai/ha	1.33 0.5	pt/a	POST	3 to 6 ft tall
3	Loyant MSO Loyant MSO	39 39	g ai/ha g ai/ha	1.33 0.5 1.33 0.5	pt/a pt/a	POST POST	0-3 ft tall 3 t- 6 ft tall
4	Loyant MSO	78	g ai/ha	2.66 0.5	pt/a	POST	0-3 ft tall
5	Loyant MSO	78	g ai/ha	2.66 0.5	pt/a	POST	3 - 6 ft tall
6	Loyant Grandstand MSO	39 420	g ai/ha g ae/ha	1.33 1.0 0.5	pt/a	POST	0-3 ft tall
7	Grandstand MSO	420	g ae/ha	1.0 0.5	pt/a	POST	3 to 6 ft tall
8	untreated check	-	-	-	-	-	-

Replications: 4, Design: Randomized Complete Block (RCB), Treatment units: Treated Plot, Experimental unit size: 3x3 m.

Table 9. Rice reinjury ratings at 7, 14, and 21 days after treatments.

TRT	PHY						CHL						NEC						STN					
DAT	7		14		21		7		14		21		7		14		21		7		14		21	
1	1	a	2	a	0	a	0	a	0	a	0	a	0	a	0	a	0	a	0	a	0	a	0	A
2	0	a	0	a	0	a	0	a	0	a	0	a	0	a	0	a	0	a	0	a	0	a	0	A
3	1	a	1	a	0	a	0	a	0	a	0	a	0	a	0	a	0	a	0	a	0	a	0	A
4	1	a	3	a	3	a	0	a	0	a	0	a	0	a	0	a	0	a	0	a	0	a	0	A
5	1	a	2	a	1	a	0	a	0	a	0	a	0	a	0	a	0	a	0	a	0	a	0	A
6	0	a	0	a	0	a	0	a	0	a	0	a	0	a	0	a	0	a	0	a	0	a	0	A
7	0	a	0	a	0	a	0	a	0	a	0	a	0	a	0	a	0	a	0	a	0	a	0	A
8	0	a	0	a	0	a	0	a	0	a	0	a	0	a	0	a	0	a	0	a	0	a	0	A

DAT, days after treatments; PHY, phytotoxicity; CHL, chlorosis; NEC, necrosis; STN, stunting. The same lowercase letters within a column indicate means are not statistically different at α=0.05.

Table 10. Percent cattail plants killed at 7, 14, 21, 28, and 42 DAT.

Treatments	7	14	21	28	42
1	0	10	45	100	100
2	17	90	100	100	100
3	0	10	66	100	100
4	0	25	60	100	100
5	25	90	100	100	100
6	9	31	51	100	100
7	0	0	0	0	0
8	0	0	0	0	0

c. Rotational Rice Weed Management Programs with SUPERWHAM! herbicide.

SuperWham, propanil, is an amide-type rice herbicide inhibitor of photosynthesis at PS II. The objective was to evaluate SuperWham efficacy as a post-emergence application alongside various herbicides for season-long control and identified the most adequate propanil herbicide program in water-seeded rice. Cerano 5 MEG (Group 13) at 8 lb/A, was applied as base treatment in all plots including untreated check. SuperWham was applied at 6 qt/A alone or in mixtures with other available post-emergent rice herbicides at mid-tiller rice stage (Table 11). Slight rice injury resulted from application of Cerano followed by SuperWham and Shark H2O. All SuperWham applications nearly resulted in 100% percent control on all weed species tested in this study (Table 12-15). SuperWham has shown a great result and provided the potential to integrate into season-long herbicide programs to achieve broad-spectrum control of rice weed species. All propanil treatment gave good yield (Table 16)

Table 11. Herbicide treatments.

No	Treatment	Rate	Unit	Timing
1	Cerano 5 MEG	8	lb/A	DOS
2	Cerano 5 MEG SuperWham	8 6	lb/A qt/A	DOS mid-tiller
3	Cerano 5 MEG SuperWham Abolish	8 6 2	lb/A qt/A pt/A	DOS mid-tiller mid-tiller
4	Cerano 5 MEG SuperWham Clincher	8 6 15	lb/A qt/A fl oz/A	DOS mid-tiller mid-tiller
5	Cerano 5 MEG SuperWham Loyant	8 6 1.33	lb/A qt/A pt/A	DOS mid-tiller mid-tiller
6	Cerano 5 MEG SuperWham Shark H2O	8 6 1	lb/A qt/A oz wt/A	DOS mid-tiller mid-tiller

Replications: 4, Design: RCBD, Treatment units: Treated Plot, Experimental unit size: 3x6 m.

Table 12. Rice response at 7, 14, and 28 days after each application.

TRT	PHY			CHL			NEC			STU		
	7	14	28	7	14	28	7	14	28	7	14	28
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0
6	10	15	0	5	10	0	10	15	0	5	10	0

TRT, Treatments; PHY, general phytotoxicity; CHL, chlorosis; NEC, necrosis; STU, stunting.

Table 13. Weed control data at 14 DAT.

Treatments	WTG	SPG	BLR	SMF	DKS
1	100	100	0	0	0
2	100	100	100	100	100
3	100	100	100	100	100
4	100	100	99	100	100
5	99	100	100	100	100
6	100	100	100	100	100

WTG, barnyardgrass and watergrass; SPG, sprangletop; BLR, bulrush; SMF, smallflower umbrellasedge; DKS, ducksalad.

Table 14. Weed control data at 28 DAT.

Treatments	WTG	SPG	BLR	SMF	DKS
1	96	100	0	0	0
2	98	100	100	100	100
3	97	100	100	100	100
4	100	100	100	100	100
5	100	100	100	100	100
6	98	100	100	100	100

WTG, barnyardgrass and watergrass; SPG, sprangletop; BLR, bulrush; SMF, smallflower umbrellasedge; DKS, ducksalad.

Table 15. Weed control data at 42 DAT.

Treatments	WTG	SPG	BLR	SMF	DKS
1	97	100	0	0	100
2	98	100	100	100	100
3	99	100	100	100	100
4	100	100	99	100	100
5	100	100	100	100	100
6	98	100	100	100	100

WTG, barnyardgrass and watergrass; SPG, sprangletop; BLR, bulrush; SMF, smallflower umbrellasedge; DKS, ducksalad.

Table 16. Rice yield of treatments at harvest.

Treatments	lb/acre	kg/hectare
1	5353	6001
2	6229	6983
3	6413	7189
4	6385	7158
5	6366	7136
6	7339	8228

Yield was adjusted at 14% grain moisture.

d. Evaluation of Efficacy of Zembu on weeds in CA rice with different flood heights and seeding timings

Zembu (Pyraclonil) was evaluated at different flood heights and seeding timings. Along with the proper treatments and application timings, copper sulfate was applied at 10 lb/ac for algae control and lambda-cyhalothrin was applied at 3.84 fl oz/A for seed midge and tadpole shrimp control.

The treatments for this study included Zembu at 14.9 lb/A at DOS 4” flood - seeding at the 4-inch flood, Zembu at 14.9 lb/A pre-seed on bare ground - seeding on the 4” flood, Zembu at 14.9 lb/A pre-seed with a 1” flood - seeding at 4” flood, and Zembu at 14.9 lb/A DOS 4” flood - seeding 3 days after the 4” flood. All treatments proved effective at weed control. Each rating showed nearly 100% control of all weeds. By 42 DAT, all treatment groups experience some ricefield bulrush emergence at Zembu at 14.9 lb/A DOS 4” flood - seeding 3 days after the 4” flood. The best control over ricefield bulrush came from Zembu at 14.9 lb/a pre-seed with a 1” flood - seeding at 4” flood with Aside from that, there is nearly 100% control over all other weeds over the duration of the study. At 7 DAT, rice injury included stunting and stand reduction for all treatments, resulting in similar readings across all treatments. The treatment with the highest stunting and stand reduction was Zembu at 14.9 lb/a pre-seed with a 1” flood - seeding at 4” flood. The other treatments are not too far behind in crop injury ratings. This no longer becomes an issue, as by 14 DAT all crop injury ratings improve greatly. The treatment that resulted in the most yield was Zembu at 14.9 lb/A pre-seed on bare ground - seeding on the 4” flood with a yield of 6670 lb/ac. The least yield came from the untreated control groups at 3975 lb/A.

e. Evaluation of Efficacy of Zembu + Strada on weeds in California water seeded rice

Zembu (Pyraclonil) and Strada (Orthosulfamuron) were evaluated at different application timings and in conjunction with each other. The objective of this study was to determine the efficacy of Zembu + Strada on weeds in rice. Copper sulfate was applied at 10 lb/ac for algae control and lambda-cyhalothrin was applied at 3.84 fl oz/a t control seed midge and tadpole shrimp control. The treatments for this study included Zembu at 14.9 lb/A DOS, Zembu at 14.9 lb/A with Strada at 2.1 oz/a DOS, and Zembu at 14.9 lb/a DOS followed by Strada at 2.1 oz/a 1.5 LSR. All treatments in this study proved effective weed control. At all rating dates, treatments showed nearly 100% control of all weeds since the first application, except for the standalone Zembu treatment on ricefield bulrush control at 28 DAT, as the mean control for this treatment was 51%. This improves significantly at 42 DAT where the mean control for bulrush is 88%. At 7 DAT, rice injury included stunting and stand reduction for all treatments. However, plant recovered from symptoms by 21 DAT as stand reduction improved greatly, but still had high amounts of stunting. Bleaching and chlorosis were not issues for this study. Zembu at 14.9 lb/a DOS followed by Strada at 2.1 oz/A 1.5 LSR had the highest levels of crop injury both at 7 DAT. The treatment that resulted in the most yield was Zembu at 14.9 lb/a DOS followed by Strada at 2.1 oz/A 1.5 LSR with a yield of 6145.3 lb/ac. The lowest yield came from the untreated control groups at 3127 lb/A.

In summary, the treatments in this study are closely matched in effectiveness in terms of weed control and crop injury. The only treatment that showed itself to be the least effective in weed control was the stand alone Zembu treatment. Applying Zembu at 14.9 lb/A DOS and Strada at 2.1 oz wt/a 1.5 LSR gives the best yield and exceptional weed control.

f. Evaluation of Efficacy of Zembu on weeds in rice under the Leather’s method.

Zembu efficacy was evaluated at different application timings and sometimes in conjunction with other herbicides. The objective of this study was to determine the efficacy of Zembu weeds in rice after leathering treatment. Treatments included Zembu at 14.9 lb/A DOS, and Zembu at 14.9 lb/A DOS followed by Clincher CA 15 fl oz/A, Loyant CA 1.33 pt/a, and COC 1% v/v at 30 DAS 2 LSR. All treatments in this study proved effective weed control. Each rating showed nearly 100% control of all weeds since the first application. At 7 DAT, rice injury mainly included stunting for all treatments. However, rice plants recovered by 21 DAT The standalone application of Zembu had the highest rates of crop injury at 7 DAT. The treatment that resulted in the highest yield was the standalone treatment of Zembu at 14.9 lb/a with a yield of 5975 lb/A. This treatment also had one of the highest average plant heights. The lowest yield was 2073 lb/A at untreated control.

Objective 2. Conduct intensive research to evaluate new herbicides that address critical weed control needs in California rice cropping systems to ensure that they are efficacious compatible, and useful for California rice production.

a. Weed control and crop safety in ROXY ® RPS

The objective of this study was to evaluate Roxy ® RPS herbicide program in California water seeded rice system. This experiment was a randomized complete block design with 3 replications. Rice variety M-521 ROXY was hand seeded at 180 lb/ac into a field flooded to 4 inches of depth with 10'x20' plots surrounded by levees on May 31, 2023, at the Rice Experiment Station near Biggs, CA.

Weed control was measured by visual ratings on a scale of 0 (no control) to 100 (weed death or no weed present) for watergrass species, bearded sprangletop, ricefield bulrush, smallflower umbrellasedge, ducksalad, and redstem. Rice injury was measured by visual ratings on a scale of 0 (no injury) to 100 (plant death) for symptoms of chlorosis, bleaching, stunting, stand reduction, and necrosis. Both weed control and crop injury ratings were collected 7, 14, 28, and 42 days after treatment (DAT) of ALB2023 (oxyfluorfen). Yield was collected by a specialized small plot harvester and grain yield was adjusted to 14% moisture. ALB2023 was applied as a preflood preemergence herbicide at both 1.75 pt/ac and 2.0 pt/ac either alone or in combination with Granite SC, Grandstand, Loyant, or Clincher at their respective rates at 5 leaf-stage rice (Table 17). Data were tested for homogeneity of variance an analyzed using ANOVA and linear regression. Means separations was performed using Tukey-Kramer's honestly significant differences at 95% significance level.

Rice injury symptoms, however, were observed from 7 DAT to 42 DAT. The only symptom observed was stunting in all ALB2023 treatments, which was significant earlier in the season then slowly recovered through 42 DAT (Table 18). Stunting ratings of 90% in all treatments was observed at 7 DAT. At 14 DAT, stunting symptoms reduced, ranging from 75-85%, and were not significantly different in any treatment. The rice had a significant recovery between 14 and 28 DAT to where the injury ranged from 0-6.5%, still not showing any significant differences. Yield data did not show any significant differences between treatments, ranging from 5,693 to 6,143 lb/ac (Table 18). Overall, rice response data of both crop injury and yield did not show any significant differences which suggests that the increased rate of 1.75 to 2.0 pt/ac of ALB2023 does not have any effect on rice variety M-521. All treatments achieved complete control of all rated weeds the entire season (Table 19).

Table 17. Herbicide treatments for ROXY trial in 2023

Herbicides	Rate	Application Timing
Untreaded Check	-	-
ALB2023	1.75 pt/ac	PRE
Granite	2.5 fl oz/ac	5 LSR
Grandstand	8 fl oz/ac	5 LSR
ALB2023	1.75 pt/ac	PRE
Granite	2.5 fl oz/ac	5 LSR
ALB2023	1.75 pt/ac	PRE
Granite	2.5 fl oz/ac	5 LSR
Loyant	1.33 pt/ac	5 LSR
Clincher	13 fl oz/ac	5 LSR
ALB2023	2 pt/ac	PRE
Granite	2.5 fl oz/ac	5 LSR
Grandstand	8 fl oz/ac	5 LSR
ALB2023	2 pt/ac	PRE
Granite	2.5 fl oz/ac	5 LSR
ALB2023	2 pt/ac	PRE
Granite	2.5 fl oz/ac	5 LSR
Loyant	1.33 pt/ac	5 LSR
Clincher	13 fl oz/ac	5 LSR
ALB2023	2 pt/ac	PRE

Table 18. Chlorosis, bleaching, stunting, stand reduction and yield of Roxy rice after treatment with ALB2023 in 2023.

Herbicides	Chlorosis[a]		Bleaching[a]		Stunting[a]		Stand Reduction[a]		Necrosis[a]		Yield[a] (lb/ac)
	DAT										
	14	42	14	42	14	42	14	42	14	42	
	%										
ALB2023 (1.75 pt/ac) fb[b] Granite SC + Grandstand	0 a	0 a	0 a	0 a	75 a	0 a	0 a	0 a	0 a	0 a	5,985
ALB2023 (1.75 pt/ac) fb Granite	0 a	0 a	0 a	0 a	78 a	0 a	0 a	0 a	0 a	0 a	5,768
ALB2023 (1.75 pt/ac) fb Granite + Loyant + Clincher	0 a	0 a	0 a	0 a	82 a	0 a	0 a	0 a	0 a	0 a	6,143
ALB2023 (2.0 pt/ac) fb Granite + Grandstand	0 a	0 a	0 a	0 a	82 a	1 a	0 a	0 a	0 a	0 a	5,790
ALB2023 (2.0 pt/ac) fb Granite	0 a	0 a	0 a	0 a	77 a	1 a	0 a	0 a	0 a	0 a	5,729
ALB2023 (2.0 pt/ac) fb Granite + Loyant + Clincher	0 a	0 a	0 a	0 a	85 a	1 a	0 a	0 a	0 a	0 a	5,693
ALB2023 (2.0 pt/ac)	0 a	0 a	0 a	0 a	80 a	0 a	0 a	0 a	0 a	0 a	6,131

a Within columns, means accompanied by the same letter do not significantly differ with Tukey's honestly significant difference (HSD) at $\alpha = 0.05$.

b fb, followed by

Table 19. Weed control ratings of watergrass species, bearded sprangletop, ricefield bulrush, smallflower umbrella sedge, ducksalad, and redstem at 14 and 42 DAT for ROXY study in 2023

Herbicides	Watergrass spp.[a]		Bearded sprangletop[a]		Ricefield Bulrsuh[a]		Smallflower umbrellasedge[a]		Ducksalad[a]		Redstem[a]	
	DAT											
	14	42	14	42	14	42	14	42	14	42	14	42
	%											
ALB2023 (1.75 pt/ac) fb[b] Granite + Grandstand	100 a	100 a	100 a	100 a	100 a	100 a	100 a	100 a	100 a	100 a	100 a	100 a
ALB2023 (1.75 pt/ac) fb Granite	100 a	100 a	100 a	100 a	100 a	100 a	100 a	100 a	100 a	100 a	100 a	100 a
ALB2023 (1.75 pt/ac) fb Granite + Loyant + Clincher	100 a	100 a	100 a	100 a	100 a	100 a	100 a	100 a	100 a	100 a	100 a	100 a
ALB2023 (2.0 pt/ac) fb Granite + Grandstand	100 a	100 a	100 a	100 a	100 a	100 a	100 a	100 a	100 a	100 a	100 a	100 a
ALB2023 (2.0 pt/ac) fb Granite	100 a	100 a	100 a	100 a	100 a	100 a	100 a	100 a	100 a	100 a	100 a	100 a
ALB2023 (2.0 pt/ac) fb Granite + Loyant + Clincher	100 a	100 a	100 a	100 a	100 a	100 a	100 a	100 a	100 a	100 a	100 a	100 a
ALB2023 (2.0 pt/ac)	100 a	100 a	100 a	100 a	100 a	100 a	100 a	100 a	100 a	100 a	100 a	100 a

b. Control of *Echinochloa* spp. and *Leptochloa fascicularis* with Novel Dihydroorotate Dehydrogenase Inhibitor Herbicide Tetflupyrolimet in California Water-seeded Rice (*Oryza sativa*)

The spread of herbicide resistant weeds is considered a major problem for rice production in California and there is a great need for new herbicides in rice. Tetflupyrolimet is a new herbicide with a novel dihydroorotate dehydrogenase (DHODH) inhibiting mode of action that has strong activity on grasses. Three field studies were conducted at the California Rice Experiment Station in Biggs, CA in 2022 and 2023 to 1) determine control of *Echinochloa spp*. (watergrass species) and *Leptochloa fascicularis* (bearded sprangletop) by tetflupyrolimet 2) characterize the effects of tetflupyrolimet combined with other herbicides on weed control and rice and 3) study differential rice varietal response by tetflupyrolimet. In the first study, tetflupyrolimet was applied at preemergence (PRE) or 1-2 leaf stage rice (POST) at 0.1, 0.125, or 0.15 kg ai ha^{-1} followed by carfentrazone, a sedge and broadleaf herbicide used to focus on the activity of tetflupyrolimet on grass weeds, at its respective timing and rate. A control treatment of carfentrazone alone, to focus on effects of grass weeds on yield, and a grower standard treatment were used for comparison. Tetflupyrolimet provided 99-100% control of watergrass species and 100% bearded sprangletop regardless of rates, or application timing, which was comparable to the grower standard. Tetflupyrolimet also showed no crop injury symptoms or yield reduction as opposed to moderate rice bleaching symptoms showed by the grower standard treatment. In the second study, tetflupyrolimet was applied at PRE or POST at 0.1 or 0.15 kg ai ha^{-1} in combination with or followed by carfentrazone, clomazone, thiobencarb, propanil, triclopyr, bensulfuron, or benzobicyclon plus halosulfuron at their respective rates and application timings (Table ???) to determine if tetflupyrolimet interacts with any of these commonly used California rice herbicides. A nontreated control and a grower standard treatment were used for comparison. Tetflupyrolimet provided 98 to 100% control of watergrass species, which was significantly superior to the grower standard treatment, and 97 to 100% control bearded sprangletop, which was comparable to the grower standard treatment. Tetflupyrolimet applied in combination with benzobicyclon plus halosulfuron, thiobencarb followed by propanil, bensulfuron followed by propanil, triclopyr and propanil, or clomazone followed by propanil provided excellent season long control of all weeds, except for redstem in some treatments, rated in these experiments without the display of any synergistic or antagonistic effects of herbicide combinations. In the third study, tetflupyrolimet was applied at PRE or POST at 0.125, 0.15, 0.25, or 0.3 kg ai ha^{-1} followed by carfentrazone at its respective timing and rate. A control treatment of carfentrazone alone and a grower standard treatment were used for comparison. California rice varieties – 'M-105,' 'M-206,' 'M-209,' 'M-211,' 'L-208,' and 'CM-203' – did not show any trend of crop injury caused by tetflupyrolimet, which was comparable to the grower standard treatment. Overall, tetflupyrolimet shows strong control of watergrass species and bearded sprangletop without causing visual rice injury or yield reductions, regardless of rice variety, when applied alone or in combination with commonly used sedge and broadleaf herbicides in California water-seeded rice.

Herbicides, rates, and application timings for tetflupyrolimet control of watergrass.

Herbicides	Rate (kg ai ha^{-1})	Application Timing
Carfentrazone	0.53	2-3 leaf annual grass
Tetflupyrolimet	0.1	Day of seeding (DOS)
Carfentrazone	0.53	2-3 leaf annual grass
Tetflupyrolimet	0.125	DOS
Carfentrazone	0.53	2-3 leaf annual grass
Tetflupyrolimet	0.125	2-3 leaf annual grass
Carfentrazone	0.53	2-3 leaf annual grass
Tetflupyrolimet	0.15	2-3 leaf annual grass
Carfentrazone	0.53	2-3 leaf annual grass
Clomazone	0.673	DOS
Penoxsulam	0.035	2-3 leaf annual grass

Herbicides, rates, and application timings for tetflupyrolimet applied in combination with sedge and broadleaf control herbicide study in 2022 and 2023.

Herbicides	Rate (kg ai ha^{-1})	Application Timing
Tetflupyrolimet	0.1	DOS
Carfentrazone	0.53	2-4 rice-leaf stage
Tetflupyrolimet	0.1	DOS
Benzobicyclon/ Halosulfuron	0.31	1-2 rice-leaf stage
Tetflupyrolimet	0.1	DOS
Thiobencarb	3.9	1-2 rice-leaf stage
Propanil	6.7	Mid rice tillering
Tetflupyrolimet	0.1	DOS
Bensulfuron	0.12	1-2 rice-leaf stage
Propanil	6.7	Mid rice tillering
Tetflupyrolimet	0.1	DOS
Triclopyr	0.16	Mid rice tillering
Propanil	6.7	Mid rice tillering
Benzobicyclon/ Halosulfuron	0.31	DOS
Tetflupyrolimet	0.15	1-2 rice-leaf stage
Clomazone	0.07	DOS
Tetflupyrolimet	0.15	1-2 rice-leaf stage
Propanil	6.7	Mid rice tillering
Benzobicyclon/ Halosulfuron	0.37	DOS
Propanil	4.48	Mid rice tillering
Propanil	4.48	Mid rice tillering + 7 days
Triclopyr	0.16	Mid rice tillering + 7 days

Herbicides, rates, and application timings for rice varietal response to tetflupyrolimet study in 2022 and 2023.

Herbicides	Rate (kg ai ha^{-1})	Application Timing
Carfentrazone	0.53	2-3 leaf annual grass
Tetflupyrolimet	0.125	DOS
Carfentrazone	0.53	2-3 leaf annual grass
Tetflupyrolimet	0.25	DOS
Carfentrazone	0.53	2-3 leaf annual grass
Tetflupyrolimet	0.15	2-3 leaf annual grass
Carfentrazone	0.53	2-3 leaf annual grass
Tetflupyrolimet	0.3	2-3 leaf annual grass
Carfentrazone	0.53	2-3 leaf annual grass
Benzobicyclon/ Halosulfuron	0.37	DOS
Propanil	4.48	Mid rice tillering
Propanil	4.48	Mid rice tillering + 7 days
Triclopyr	0.16	Mid rice tillering + 7 days

Rice bleaching at 14 and 28 DAT for tetflupyrolimet control of watergrass species and bearded sprangletop study in 2023 at sites 1 and 2.

Herbicides	DAT			
	Site 1[a]		Site 2[a]	
	14	28	14	28
	%			
Tetflupyrolimet (PRE 0.1 kg ai ha^{-1}) fb[b] carfentrazone	0 a	0 a	0 a	0 a
Tetflupyrolimet (PRE 0.125 kg ai ha^{-1}) fb carfentrazone	0 a	0 a	0 a	0 a
+Tetflupyrolimet (POST 0.125 kg ai ha^{-1}) fb carfentrazone	0 a	0 a	0 a	0 a
Tetflupyrolimet (POST 0.15 kg ai ha^{-1}) fb carfentrazone	0 a	0 a	0 a	0 a
Clomazone fb penoxsulam	50 b	0 a	32 b	0 a

[a] Within columns, means accompanied by the same letter do not significantly differ with Tukey's honestly significant difference (HSD) at α = 0.05.

[b] fb, followed by

Yield for tetflupyrolimet control of watergrass species and bearded sprangletop study averaged across sites 1 and 2 in 2023.

Herbicides	Rate (lb ai ac^{-1})	Application Timing	Avg Yield (lb ac^{-1})
Carfentrazone	0.47	2-3 leaf annual grass	5,247
Tetflupyrolimet Carfentrazone	0.09 0.47	Day of seeding (DOS) 2-3 leaf annual grass	5,234
Tetflupyrolimet Carfentrazone	0.11 0.47	DOS 2-3 leaf annual grass	5,158
Tetflupyrolimet Carfentrazone	0.11 0.47	2-3 leaf annual grass 2-3 leaf annual grass	5,146
Tetflupyrolimet Carfentrazone	0.13 0.47	2-3 leaf annual grass 2-3 leaf annual grass	5,616
Clomazone Penoxsulam	0.6 0.03	DOS 2-3 leaf annual grass	4,804

Rice chlorosis, stunting, stand reduction, and necrosis at 14 and 28 DAT with for tetflupyrolimet control of watergrass species and bearded sprangletop study in 2023 at sites 1 and 2.

Herbicides	DAT							
	Chlorosis[a]		Stunting[a]		Stand Reduction[a]		Necrosis[a]	
	14	28	14	28	14	28	14	28
	%							
Tetflupyrolimet (PRE 0.1 kg ha^{-1}) fb[b] carfentrazone	0 a	1 a	0 a	1 a	1 a	0 a	0 a	0 a
Tetflupyrolimet (PRE 0.125 kg ha^{-1}) fb carfentrazone	0 a	2 a	0 a	5 a	0 a	8 a	0 a	0 a
Tetflupyrolimet (POST 0.125 kg ha^{-1}) fb carfentrazone	0 a	8 a	3 a	8 a	12 a	1 a	0 a	0 a
Tetflupyrolimet (POST 0.15 kg ha^{-1}) fb carfentrazone	2 a	2 a	0 a	3 a	0 a	0 a	0 a	0 a
Clomazone fb penoxsulam	0 a	3 a	0 a	12 a	3 a	1 a	0 a	0 a

Average percent weed control at 14 and 56 DAT for tetflupyrolimet applied in combination with sedge and broadleaf control herbicide study in 2022.

Herbicides	Watergrass spp.[a]		Bearded sprangletop[a]		Ricefield Bulrsuh[a]		Smallflower umbrellasedge[a]		Ducksalad[a]		Redstem[a]	
	DAT											
	14	56	14	56	14	56	14	56	14	56	14	56
	%											
Tetflupyrolimet fb[b] carfentrazone	99 b	99 b	100 a	98 a	100 a	88 a	100 a	72 a	100 a	90 a	100 a	100 b
Tetflupyrolimet fb benzobicyclon/ halosulfuron	99 b	99 b	100 a	100 a	100 a	100 a	100 a	100 b	100 a	100 a	100 a	82 b
Tetflupyrolimet fb thiobencarb fb propanil	99 b	99 b	100 a	100 a	100 a	97 a	100 a	100 b	100 a	100 a	100 a	100 b
Tetflupyrolimet fb bensulfuron fb propanil	100 b	100 b	100 a	97 a	100 a	99 a	100 a	96 b	100 a	100 a	100 a	100 b
Tetflupyrolimet fb triclopyr + propanil	100 b	100 b	100 a	99 a	100 a	99 a	100 a	97 b	100 a	100 a	100 a	100 b
Benzobicyclon/ halosulfuron fb tetflupyrolimet	98 b	98 b	100 a	100 a	100 a	100 a	100 a	100 b	100 a	100 a	100 a	33 a
Clomazone fb tetflupyrolimet fb propanil	99 b	99 b	100 a	100 a	100 a	100 a	100 a	97 b	100 a	100 a	100 a	100 b
Benzobicyclon/ halosulfuron fb propanil fb propanil + triclopyr	94 a	94 a	100 a	99 a	100 a	100 a	100 a	100 b	100 a	100 a	100 a	99 b

[a] Within columns, means accompanied by the same letter do not significantly differ with Tukey's honestly significant difference (HSD) at α = 0.05.

[b] fb, followed by

Average percent weed control at 14 and 56 DAT for tetflupyrolimet applied in combination with sedge and broadleaf control herbicide study in 2023.

Herbicides	Watergrass spp.[a]		Bearded sprangletop[a]		Ricefield Bulrsuh[a]		Smallflower umbrellasedge[a]		Ducksalad[a]		Redstem[a]	
	DAT											
	14	56	14	56	14	56	14	56	14	56	14	56
	%											
Tetflupyrolimet fb[b] carfentrazone	100 a	100 a	100 b	100 a	95 a	77 a	100 b	83 a	100 a	83 a	100 b	97 a
Tetflupyrolimet fb benzobicyclon/ halosulfuron	100 a	100 a	100 b	100 a	40 a	100 a	100 b	100 a	100 a	100 b	100 b	63 a
Tetflupyrolimet fb thiobencarb fb propanil	99 a	100 a	100 b	100 a	98 a	100 a	100 b	100 a	100 a	100 b	100 b	65 a
Tetflupyrolimet fb bensulfuron fb propanil	100 a	100 a	100 b	100 a	100 a	100 a	100 b	100 a	100 a	100 b	100 b	92 a
Tetflupyrolimet fb triclopyr + propanil	100 a	100 a	100 b	100 a	65 a	100 a	100 b	100 a	43 a	98 ab	100 b	97 a
Benzobicyclon/ halosulfuron fb tetflupyrolimet	99 a	100 a	100 b	100 a	99 a	100 a	99 b	100 a	100 a	100 b	100 b	73 a
Clomazone fb tetflupyrolimet fb propanil	100 a	100 a	100 b	100 a	50 a	98 a	100 b	98 a	50 a	97 ab	100 b	97 a
Benzobicyclon/ halosulfuron fb propanil fb propanil + triclopyr	100 a	100 a	99 a	100 a	98 a	100 a	96 a	100 a	100 a	100 b	0 a	100 a

Yield for tetflupyrolimet applied in combination with sedge and broadleaf control herbicide study in 2022

Herbicides	Rate (lb ai ac^{-1})	Application Timing	Avg Yield (lb ac^{-1})
Untreated Control	-	-	3,289
Tetflupyrolimet Carfentrazone	0.09 0.47	DOS 2-4 rice-leaf stage	6,981
Tetflupyrolimet Benzobicyclon/ Halosulfuron	0.09 0.28	DOS 1-2 rice-leaf stage	8,249
Tetflupyrolimet Thiobencarb Propanil	0.09 3.48 5.98	DOS 1-2 rice-leaf stage Mid rice tillering	8,522
Tetflupyrolimet Bensulfuron Propanil	0.09 0.11 5.98	DOS 1-2 rice-leaf stage Mid rice tillering	7,633
Tetflupyrolimet Triclopyr Propanil	0.09 0.14 5.98	DOS Mid rice tillering Mid rice tillering	7,053
Benzobicyclon/ Halosulfuron Tetflupyrolimet	0.28 0.13	DOS 1-2 rice-leaf stage	7,634
Clomazone Tetflupyrolimet Propanil	0.06 0.13 5.98	DOS 1-2 rice-leaf stage Mid rice tillering	6,905
Benzobicyclon/ Halosulfuron Propanil Propanil Triclopyr	0.33 4.0 4.0 0.14	DOS Mid rice tillering Mid rice tillering + 7 days Mid rice tillering + 7 days	8,135

Yield for tetflupyrolimet applied in combination with sedge and broadleaf control herbicide study in 2023

Herbicides	Rate (lb ai ac^{-1})	Application Timing	Avg Yield (lb ac^{-1})
Untreated			
Control	-	-	2,622
Tetflupyrolimet	0.09	DOS	
Carfentrazone	0.47	2-4 rice-leaf stage	5,934
Tetflupyrolimet	0.09	DOS	
Benzobicyclon/	0.28	1-2 rice-leaf stage	6,249
Halosulfuron			
Tetflupyrolimet	0.09	DOS	
Thiobencarb	3.48	1-2 rice-leaf stage	6,203
Propanil	5.98	Mid rice tillering	
Tetflupyrolimet	0.09	DOS	
Bensulfuron	0.11	1-2 rice-leaf stage	7,050
Propanil	5.98	Mid rice tillering	
Tetflupyrolimet	0.09	DOS	
Triclopyr	0.14	Mid rice tillering	6,645
Propanil	5.98	Mid rice tillering	
Benzobicyclon/	0.28	DOS	
Halosulfuron		1-2 rice-leaf stage	6,346
Tetflupyrolimet	0.13		
Clomazone	0.06	DOS	
Tetflupyrolimet	0.13	1-2 rice-leaf stage	6,586
Propanil	5.98	Mid rice tillering	
Benzobicyclon/	0.33	DOS	
Halosulfuron		Mid rice tillering	
Propanil	4.0	Mid rice tillering + 7 days	7,088
Propanil	4.0	Mid rice tillering + 7 days	
Triclopyr	0.14		

Rice necrosis at 14 and 28 DAT for the rice varietal response to tetflupyrolimet study in 2022 and 2023.

Herbicides	Variety	Necrosis[a] 2022		2023	
		DAT			
		14	28	14	28
		%			
Tetflupyrolimet (PRE 0.125 kg ai ha^{-1}) fb[b] carfentrazone	M-105	0 a	5 a	0 a	0 a
	M-206	0 a	5 a	0 a	0 a
	M-209	0 a	5 a	0 a	0 a
	M-211	0 a	5 a	0 a	0 a
	L-208	0 a	5 a	0 a	0 a
	CM-203	0 a	5 a	0 a	0 a
Tetflupyrolimet(PRE 0.25 kg ai ha^{-1}) fb carfentrazone	M-105	0 a	5 a	0 a	0 a
	M-206	2 a	5 a	0 a	0 a
	M-209	2 a	5 a	0 a	0 a
	M-211	0 a	5 a	0 a	0 a
	L-208	2 a	5 a	0 a	0 a
	CM-203	0 a	5 a	0 a	0 a
Tetflupyrolimet (POST 0.25 kg ai ha^{-1}) fb carfentrazone	M-105	5 ab	5 a	0 a	0 a
	M-206	10 c	7 a	0 a	0 a
	M-209	8 bc	5 a	0 a	0 a
	M-211	5 ab	5 a	0 a	0 a
	L-208	5 ab	5 a	0 a	0 a
	CM-203	7 b	7 a	0 a	0 a
Tetflupyrolimet (POST 0.3 kg ai ha^{-1}) fb carfentrazone	M-105	7 b	5 a	0 a	0 a
	M-206	8 bc	5 a	0 a	0 a
	M-209	10 c	5 a	0 a	0 a
	M-211	8 bc	5 a	0 a	0 a
	L-208	5 ab	5 a	0 a	0 a
	CM-203	7 b	7 a	0 a	0 a
Benzobicyclon/ halosulfuron fb propanil fb propanil + triclopyr	M-105	7 b	5 a	0 a	0 a
	M-206	7 b	5 a	0 a	0 a
	M-209	10 c	5 a	0 a	0 a
	M-211	10 c	5 a	0 a	0 a
	L-208	5 ab	3 a	0 a	0 a
	CM-203	5 ab	7 a	0 a	0 a

[a] Within columns, means accompanied by the same letter do not significantly differ with Tukey's honestly significant difference (HSD) at $\alpha = 0.05$. b fb, followed by

Yield for rice varietal response to tetflupyrolimet study in 2023

Herbicides	Rate (lb ai ac^{-1})	Application Timing	Avg Yield (lb ac^{-1})
Carfentrazone	0.47	2-3 leaf annual grass	CM-203: 6,557 L-208: 5,970 M-105: 6,072 M-206: 5,801 M-209: 6,208 M-211: 6,395
Tetflupyrolimet Carfentrazone	0.11 0.47	DOS 2-3 leaf annual grass	CM-203: 6,117 L-208: 6,021 M-105: 5,027 M-206: 5,096 M-209: 6,367 M-211: 6,487
Tetflupyrolimet Carfentrazone	0.22 0.47	DOS 2-3 leaf annual grass	CM-203: 5,995 L-208: 6,577 M-105: 5,933 M-206: 6,105 M-209: 6,173 M-211: 7,214
Tetflupyrolimet Carfentrazone	0.13 0.47	2-3 leaf annual grass 2-3 leaf annual grass	CM-203: 6,135 L-208: 6,050 M-105: 5,375 M-206: 6,107 M-209: 6,013 M-211: 6,693
Tetflupyrolimet Carfentrazone	0.27 0.47	2-3 leaf annual grass 2-3 leaf annual grass	CM-203: 6,181 L-208: 5,140 M-105: 5,784 M-206: 5,787 M-209: 6,258 M-211: 6,807
Benzobicyclon/ Halosulfuron Propanil Propanil Triclopyr	0.33 4.0 4.0 0.14	DOS Mid rice tillering Mid rice tillering + 7 days Mid rice tillering + 7 days	CM-203: 6,762 L-208: 5,890 M-105: 6,245 M-206: 6,071 M-209: 6,579 M-211: 7,143

Nontreated control

Tetflupyrolimet

c. Prowl H2O (pendimethalin) herbicide optimization in water seeded rice.

Pendimethalin is a potential new herbicide to introduce to water-seeded rice because it controls important watergrass species and *Leptochloa fusca*, and has shown to control herbicide-resistant populations of these species (personal observation). Pendimethalin is a WSSA Group 3, mitotic-inhibiting, herbicides that ceases seedling growth shortly after germination. Previous field and greenhouse studies of pendimethalin formulations demonstrated the potential for its use in water-seeded rice. The results showed the capsule suspension (CS) formulation at the 4- to 5-leaf stage rice was appropriate for reducing rice injury. However, at this stage weed control levels were decreased when applied alone. Therefore, application in herbicide mixtures may be most appropriate in an early-postemergence application. Additionally, an application of pendimethalin after a base or day of seeding herbicide to overlay the soil herbicide residual activity could be another approach to integrate this pendimethalin in our system. Preliminary trials in the field and greenhouse also demonstrated some degree of recovery in rice seedlings when application occurred at a 3-leaf stage application. A pendimethalin application at this stage can produce greater weed control levels; however, yield decrease from rice injury could be an issue. Previous cultivar response studies conducted showed seedling vigor was an important factor to incur relative tolerance of pendimethalin. The cultivar seedlings that established faster resulted in decreased injury levels when application occurred at the 1-leaf stage. While all cultivars tested were relatively tolerant to the soil applied pendimethalin at a 3-leaf stage application. Therefore, there can be potential to apply pendimethalin earlier in the field.

The Leathers' Methods is commonly used by water-seeded rice growers, especially in times when environmental factors are not favorable early on and may affect seedling establishment in a flooded field, like strong winds. If a Leather's Method allows for faster seedling establishment by lowering the flood level in the field, then, a pendimethalin application after a Leathers' Method may reduce injury to adequate levels and allow for an earlier application timing of pendimethalin which can provide greater weed control potential.

Four field studies were conducted in the 2023 growing season to examine rice response and weed control efficacy of pendimethalin at different timings and in herbicide mixtures for season-long control herbicide programs. The studies included

1. Efficacy of pendimethalin in herbicide mixtures applied post-emergence at different rates (2nd year of study)
2. Efficacy of pendimethalin as an overlay post-emergence residual application for season-long weed control
3. Rice response to pendimethalin herbicide mixture applications at 3- and 5-leaf stage
4. Efficacy and rice response of pendimethalin at 3- and 5-leaf stage as affected by flood management

The objectives of the studies where to further understand and optimize the use of pendimethalin in water-seeded rice.

The studies were conducted at the Rice Experiment Station in Biggs, CA (Hamilton Road). The soils at the site are characterized as silty clay, made up of 27% sand, 39% silt, and 34% clay, with a pH of 5.1, and 2.8% organic matter. The fields were not flooded during the winter season. At the beginning of the season the soil was passed with a chisel plow, followed by an offset disc a week later. A land plane was then passed over to smooth the soil surface followed by fertilization by airplane at 300 lbs/ac with an

N, P, K (102, 51, 0) mixture granule fertilizer. Then, a corrugated roller was passed over to break up large clods and put small ridges on the soil surface. Individual 3-m wide by 6-m long plots surrounded by 2.2-m wide shared levees were made to prevent contamination from adjacent treatments in a replication. Seeds of the rice cultivar 'M-209' were pregerminated in steel bins filled with water until all the seeds were completely covered. For disease control, a 5% sodium hypochlorite solution was added in the water for the first hour, then drained and refilled with only water for the remaining 24 hours. The seed was then drained until dry, and air-seeded by aircraft at 150 lbs/ac seeding rate onto the field with a 4-inch standing flood. Seeding dates were June 1st, 2023, in the South Field and June 2nd, 2023, in the North Field. The south field had study number 1 and the South Field had studies 2 to 4, as listed above. The 4-inch flood was maintained during the study and only receded for herbicide applications, except for study 4. In study 4, Leathers' Method was carried out by draining the respective plots three days after seeding with a small water pump (Honda) and remained drained for eight days before the 3-leaf stage application. All other plots were only drained the day before or day of prior to the herbicide application.

The pendimethalin CS formulation was BAS 455 48H (Prowl H2O, BASF) with 0.5 kg L^{-1} of active ingredient. The tables show the herbicide mixtures with pendimethalin and accompanied herbicides for the season in each study (Table 1). The treatments were applied with a C02 backpack sprayer calibrated at 28 psi to deliver 20 GPA. The sprayer boom was 10-ft wide with six flat-fan 8002VS tips.

Visual percent weed control of the nontreated for *Echinochloa* spp., bearded sprangletop, small flower umbrella sedge, rice field bulrush, ducksalad, water hyssop and redstem were recorded on 14, 24 and 56 days after pendimethalin treatment (DAT) or 14, 28 and 42 DAT, on a scale of 0 to 100, where 0=no control and 100=complete control. Weed counts with a randomly placed 1-ft by 1-ft quadrat in each plot were conducted 28 DAT. Visual percent rice injury assessments were carried out at 20 DAT and 40 DAT or 7, 14, and 42 DAT by observing present symptomology, which included stunting and stand reduction, compared to the nontreated, on a scale of 0 to 100, where 0=no injury and 100=plant death. Rice stands and/or tiller counts were conducted at by sampling twice with a randomly placed 1-ft by 1-ft quadrat in each plot. Rice grain yield was collected and adjusted to 14% moisture. Data were analyzed on ARM (Agricultural Research Manager 2023, GDM Solutions Inc.) with analysis of variance and mean separation using the least significant difference (LSD) α=0.05. The data presented in this report summarize the major conclusions observed from the studies.

Efficacy of pendimethalin in herbicide mixtures applied post-emergence at different rates (2nd year of study)

Control of Echinochloa was 25 to 61% at 14 DAT (after 4 to 5 LS application) when Prowl H2O was applied alone, however, in herbicide mixtures control levels were 75 to 100% (Table 1). Following the mid-till application Echinochloa control levels increased in some treatments, but most important the additional application provided control over the sedges and broadleaf weeds present (Table 20). Sprangletop pressure was minimal at the site location and control is presented as the number of headed sprangletop plants in the plots at 24 DAT. Most treatments achieved greater control of sprangletop when compared to the nontreated, however, the herbicide mixture did affect the overall control levels (Table 20)**.** The mixtures with Clincher achieved great control of sprangletop, while the SuperWham and Regiment mixtures showed some escapes. This is no surprise since Clincher has greater activity on sprangletop. The mixtures with Prowl H2O can still be important to provide different modes of action interfering with the weed's growth.

Visual rice response was very minimal across treatments and continued throughout the season (Table 20). All herbicide mixture treatments had similar rice stand to the standard treatment of Cerano at

DOS. Only the Prowl H2O alone treatments had some reduction in stand and most likely because of increased weedy grass interference after the initial application which did not provide adequate control levels. Rice grain yield was similar across treatments and greater than the nontreated (Table 20). The results from this year's study are similar to the previous year's results. There is value of Prowl H2O to be used in water-seeded rice when used in herbicide mixtures as a post-emergence application.

Efficacy of pendimethalin as an overlay post-emergence residual application for season-long weed control

There was excellent control of grasses across treatments (Table 21). Cerano works very well at this site and while the Prowl H2O addition did not demonstrate a significant benefit it provides an additional mode of action for weedy grass control on possible late-emerging grasses. The study will be important to conduct in additional sites the following years. While the focus of this study was on grass control, the mixtures did have varying control levels on the sedge and broadleaves (data not shown on table). The SuperWham application may have been too early to achieve greater control of sedges when not mixed with Grandstand.

Rice injury at 7 DAT was minimal and similar across treatments and the rice soon recovered from any visual injury (Table 21). The treatments with herbicide mixture that controlled the sedges well achieved the highest yields at 5,574 to 5,790 lbs/ac. The treatment with Cerano and Prowl H2O only, had yields similar to the nontreated (Table 21). The results demonstrate the potential for Prowl H2O applications in water-seeded rice, but also demonstrate Prowl H2O needs to be accompanied by other herbicides to provide adequate control and yields.

Rice response from pendimethalin herbicide mixture applications at 3- and 5-leaf stage

Excellent control of grasses was achieved at both application timings on all treatments (Table 22). This is most likely because of the herbicides used early on have great grass control. Varying levels of control was achieved on the sedges and broadleaves based on the herbicide mixtures used (Table 22). A 3-leaf application was too early for sedge control with the herbicides used.

Visual injury was greater at 7 DAT after the 3-leaf stage applications; however, similar injury level was also observed in the 5-leaf stage application with Regiment mixture (Table 22). The herbicide mixtures affect the observed injury levels. Root stunting from the nodal roots of the rice seedlings was observed on the 3-leaf stage application and accounted for the injury observed, however, the rice seedlings recovered, and no visual injury was observed by 42 DAT (Table 22). The addition of Regiment in the mixtures applied at the 3-leaf stage influenced the rice grain yield, while all other treatments had greater yields than the nontreated ranging from 4,742 to 5,559 lbs/ac (Table 22). No standard treatment to compare with was added to this study, yet, it appears Prowl H2O at 3- and 5-leaf stage application did not cause significant rice injury. A 3-leaf stage Prowl H2O application may also be applicable for water-seeded rice.

Efficacy and rice response of pendimethalin at 3- and 5-leaf stage as affected by flood management

At 14 DAT, *Echinochloa* control was 95% after a Leathers' method at 3-leaf stage and 7% less control at 5-leaf stage application. While with the pinpoint applications control was greater than 92% (Table 23). The flood provides weed suppression and the Leathers' method increased the weed pressure in the plots. Sprangletop control appeared to be lower after a Leathers' method 3-leaf stage, however, there was no significance difference (Table 23). Delaying the herbicide application to 5-leaf stage caused a reduction in weed control. If performing a Leathers' method, a 3-leaf stage Prowl H2O and other herbicide application is most appropriate. Control levels increased by 42 DAT with the following applications. The additional herbicides provided excellent control of sedges and broadleaves.

Visual rice injury was observed. Root and shoot stunting were observed from the 3-leaf stage applications up to 20%, but the seedlings recovered. Stand was not affected by the herbicide treatments (Table 23). All treatments had rice grain yields greater than the nontreated and ranged from 5,803 to 6,804 lbs/ac (Table 4). While visual injury was observed, it did not significantly affect yield and the use of a Leathers' method appeared to improve rice seedling tolerance to pendimethalin. A repeated study will be necessary to understand and optimize the use of Prowl H2O. The study demonstrates the applicability of Prowl H2O in water-seeded rice and with current cultural methods.

The results from this year's studies demonstrate the potential and applicability of Prowl H2O in water-seeded rice. They also provide data to support registration. Additional repeated studies are necessary to optimize Prowl H2O in water-seeded rice.

Table 20. Prowl H2O in herbicide mixtures applied post-emergence at different rates in water-seeded rice, 2023 field study[abcde]

Herbicide Treatments	Rate	Timing	Weed control: Echinochloa 14 DAT	Echinochloa 56 DAT	Sprangletop 24 DAT	Smallflower umbrella sedge 14 DAT	Smallflower umbrella sedge 56 DAT	Rice field bulrush 14 DAT	Rice field bulrush 56 DAT	Rice response: Overall injury 20 DAT	Rice grain yield 155 DAS
			%	%	count plot^{-2}	%	%	%	%	%	lbs/ac
Prowl H20	1 lb ai/ac	4-5 LSR	25	98	0	0	83	0	83	13	5,820
Clincher	15 fl oz/ac										
Loyant	1.33 pt/ac	Mid-Till									
MSO	0.5 pt/ac										
Prowl H20	2 lb ai/ac	4-5 LSR	54	99	1	3	83	0	83	11	6,141
Clincher	15 fl oz/ac										
Loyant	1.33 pt/ac	Mid-Till									
MSO	0.5 pt/ac										
Prowl H20	4 lb ai/ac	4-5 LSR	61	98	0	3	75	0	73	15	4,725
Clincher	15 fl oz/ac										
Loyant	1.33 pt/ac	Mid-Till									
MSO	0.5 pt/ac										
Prowl H20	1 lb ai /ac		80	98	2	60	100	26	100	4	6,969
SuperWham	3 qt/ac	4-5 LSR									
COC	1 %v/v										
SuperWham	5 qt/ac										
Grandstand	12 oz/ac	Mid-Till									
NIS	0.25 %v/v										
Prowl H20	1 lb ai /ac		100	100	0	0	100	0	100	5	6,796
Clincher	13 fl oz/ac	4-5 LSR									
COC	2.5 %v/v										
SuperWham	6 qt/ac										
Grandstand	12 oz/ac	Mid-Till									
NIS	0.25 %v/v										
Prowl H20	1 lb ai /ac		76	97	2	64	99	59	99	1	6,926
Regiment	0.53 oz/ac	4-5 LSR									
MSO	0.25 %v/v										
SuperWham	6 qt/ac										
Grandstand	12 oz/ac	Mid-Till									
NIS	0.25 %v/v										
Prowl H20	2 lb ai /ac	4-5 LSR	88	100	2	65	100	60	100	4	6,276
SuperWham	3 qt/ac										

COC	1 %v/v										
SuperWham	5 qt/ac										
Grandstand	12 oz/ac	Mid-Till									
NIS	0.25 %v/v										
Prowl H20	2 lb ai /ac		100	100	0	0	99	0	98	6	6,431
Clincher	13 fl oz/ac	4-5 LSR									
COC	2.5 % v/v										
SuperWham	6 qt/ac										
Grandstand	12 oz/ac	Mid-Till									
NIS	0.25 %v/v										
Prowl H20	2 lb ai /ac		76	98	5	48	100	43	100	1	7,358
Regiment	0.53 oz/ac	4-5 LSR									
MSO	0.25 %v/v										
SuperWham	6 qt/ac										
Grandstand	12 oz/ac	Mid-Till									
NIS	0.25 %v/v										
Prowl H20	4 lb ai /ac		89	99	3	64	100	27	100	3	6,691
SuperWham	3 qt/ac	4-5 LSR									
COC	1 %v/v										
SuperWham	5 qt/ac										
Grandstand	12 oz/ac	Mid-Till									
NIS	0.25 %v/v										
Prowl H20	4 lb ai /ac		100	100	0	0	99	0	99	9	5,949
Clincher	13 fl oz/ac	4-5 LSR									
COC	2.5 % v/v										
SuperWham	5 qt/ac										
Grandstand	12 oz/ac	Mid-till									
NIS	0.25 %v/v										
Prowl H20	4 lb ai /ac		75	98	1	56	100	50	100	2	6,798
Regiment	0.53 oz/ac	4-5 LSR									
MSO*	0.25 %v/v										
SuperWham	5 qt/ac										
Grandstand	12 oz/ac	Mid-Till									
NIS	0.25 %v/v										
Cerano 5 MEG	12 lbs/ac	DOS	98	100	0	0	100	0	100	2	6,969
SuperWham	5 qt/ac										
Grandstand	12 oz/ac	Mid-till									
NIS	0.25 %v/v										

Nontreated	-	-	0	0	6	0	0	0	0	0	4,143
LSD α=0.05			13	2	3	30	2	30	2	7	1,707

[a]The 4-5 leaf stage timing was 17 days after seeding, while the mid-till application was 33 days after seeding.
[b]Data were collected days after the initial Prowl H2O application.
[c]Sprangletop population was minimal in the study site and counts of headed plants was recorded for each plot of 10 ft by 20 ft.
[d]MSO for Regiment CA used was DynAmic.
[e]DAT, days after treatment; LSR, leaf stage rice; MSO, methylated seed oil; COC, crop oil concentrate; NIS, non-ionic surfactant; DOS, day of seeding; LSD, least significant difference.

Table 21. Prowl H2O applied post-emergence and extending herbicide residual activity in water-seeded rice, 2023 field study[abcde]

Herbicide Treatments	Rate	Timing	Weed control			Rice response		
			Echinochloa		Sprangletop	Rice injury		Rice grain yield
			14 DAT	42 DAT	42 DAT	7 DAT	42 DAT	154 DAS
			%					lbs/ac
Nontreated	-	-	0	0	0	0	0	2,110
Cerano 5 MEG	10 lbs/ac	DOS	99	100	100	11	0	3,586
Prowl H20	2 lbs ai/ac	4 LSR						
Cerano 5 MEG	10 lbs/ac	DOS	99	100	100	14	5	4,113
Prowl H20	2 lbs ai/ac							
SuperWham	5 qt/ac	4 LSR						
COC	1% v/v							
Cerano 5 MEG	10 lbs/ac	DOS	100	100	100	19	3	5,655
Prowl H20	2 lbs ai/ac							
SuperWham	5 qt/ac	4 LSR						
Grandstand	7 oz/ac							
COC	1% v/v							
Cerano 5 MEG	10 lbs/ac	DOS	99	100	100	24	0	5,574
SuperWham	5 qt/ac	4 LSR						
COC	1% v/v							
Cerano 5 MEG	10 lbs/ac	DOS	100	100	100	21	0	5,790
SuperWham	*5 qt/ac							
Grandstand	7 oz/ac	4 LSR						
COC	1% v/v							
LSD α=0.05	-	-	3	0.3	-	16	4	1,506

[a]The 4 leaf stage timing was 17 days after seeding.
[b]Data were collected days after the Prowl H2O application.
[c]Treatment 6* had an erroneous application of SuperWham! CA where instead of 5 qt it was 10 qt.
[d]Rice injury is presented from stunting ratings in the ARM file which where the injury ratings with greatest observance.
[e]DAT, days after treatment; DOS, day of seeding; LSR, leaf stage rice; COC, crop oil concentrate; LSD, least significant difference.

Table 22. Weed control and rice response from Prowl H20 herbicide mixtures application at 3-leaf stage and 5-leaf stage in water-seeded rice, 2023 field study

			Weed control						Rice response		
			Echinochloa		Sprangletop	Smallflower	Ricefield bulrush	Ducksalad	Stunting injury		Rice grain yield
Herbicide Treatments	Rate	Timing	14 DAT	42 DAT	42 DAT	42 DAT	42 DAT	42 DAT	7 DAT	42 DAT	
			%								lbs/ac
Nontreated	-	-	0	0	0	0	0	0	0	0	2,081
Cerano 5 MEG	8 lb/ac	DOS	100	100	100	88	63	65	28	0	4,742
Prowl H20	2 lb ai/ac										
Clincher	13 fl oz/ac										
SuperWham	3 qt/ac	3 LS									
Grandstand	7 oz/ac										
COC	2.5 %v/v										
Cerano 5 MEG	8 lb/ac	DOS	100	100	100	53	0	68	26	0	2,242
Prowl H20	2 lb ai/ac										
Clincher	13 fl oz/ac										
Regiment	0.53 oz/ac	3 LS									
Grandstand	7 oz/ac										
COC	2.5 %v/v										
Cerano 5 MEG	8 lb/ac	DOS	100	100	100	66	56	70	11	0	5,559
Prowl H20	2 lb ai/ac										
Clincher	13 fl oz/ac										
SuperWham	3 qt/ac	5 LS									
Grandstand	7 oz/ac										
COC	2.5 %v/v										
Cerano 5 MEG	8 lb/ac	DOS	100	100	100	65	50	70	22	0	4,925
Prowl H20	2 lb ai/ac										
Clincher	13 fl oz/ac										
Regiment	0.53 oz/ac	5 LS									
Grandstand	7 oz/ac										
COC	2.5 %v/v										
LSD α=0.05			31	-	-	44	46	41	13	-	1,338

[a]The 3-leaf stage timing was 13 days after seeding and 5-leaf stage timing was 24 days after seeding.
[b]Data were collected days after the Prowl H2O applications.
[c]Rice injury is presented from stunting ratings in the ARM file which where the injury ratings with greatest observance.
[d]DAT, days after treatment; DOS, day of seeding; LSR, leaf stage rice; COC, crop oil concentrate; LSD, least significant difference.

Table 23. Prowl H20 applied after a Leathers' Method and Pinpoint application in herbicide mixtures at 3- and 5-leaf stage rice, 2023 field study[abcdef]

Herbicide Treatments	Rate	Timing	Weed control: Echinochloa 14 DAT	Weed control: Echinochloa 42 DAT	Weed control: Sprangletop 42 DAT	Rice response: Rice stand count 0 DAT	Rice response: Rice stand count 14 DAT	Rice response: Rice grain yield 155 DAS
			%			count ft^{-2}		lbs/ac
Nontreated	-	-	0	0	0	9	18	2,146
Leathers' Method			95	100	75	19	16	6,672
Prowl H20	2 lbs ai/ac							
Clincher	13 fl oz/ac	3 LS						
COC	2.5 %v/v							
SuperWham! CA	5 qt/ac							
Grandstand	7 oz/ac	Mid-Till						
NIS	0.25 %v/v							
Leathers' Method			89	99	100	14	17	5,875
Prowl H20	2 lbs ai/ac							
Clincher	13 fl oz/ac	5 LS						
COC	2.5 %v/v							
SuperWham! CA	5 qt/ac							
Grandstand	7 oz/ac	Mid-Till						
NIS	0.25 %v/v							
Pinpoint			98	100	95	19	13	6,614
Prowl H20	2 lbs ai/ac							
Clincher	13 fl oz/ac	3 LS						
COC	2.5 %v/v							
SuperWham	5 qt/ac							
Grandstand	7 oz/ac	Mid-Till						
NIS	0.25 %v/v							
Pinpoint			92	99	100	11	15	6,804
Prowl H20	2 lbs ai/ac							
Clincher	13 fl oz/ac	5 LS						
COC	2.5 %v/v							
SuperWham	5 qt/ac							
Grandstand	7 oz/ac	Mid-Till						
NIS	0.25 %v/v							
SuperWham	5 qt/ac		0	62	49	15	-	5,803
Grandstand	7 oz/ac	Mid-Till						
NIS	0.25 %v/v							
LSD α=0.05			6	11	49	7	6	1,250

[a]The 3-leaf stage timing was 13 days after seeding and 5-leaf stage timing was 24 days after seeding.

[b]The Leathers' Method was applied 3 days after seeding and reflooded 8 days after and before the 3-leaf stage application.
[c]The pinpoint was applied by draining the plot up to 12 hours before the application and reflooded 48 hours after.
[d]Data were collected days after the Prowl H2O applications at their respective timing.
[e]Rice stand sampled from two areas within each plot.
[f]DAT, days after treatment; DOS, day of seeding; LSR, leaf stage rice; COC, crop oil concentrate; LSD, least significant difference.

d. Saflufenacil efficacy study

A study with saflufenacil in water-seeded rice was conducted in the 2023 field season. Saflufenacil is a PPO-inhibiting herbicide commonly used in rice production systems for control on broadleaf weeds, however, not in water-seeded rice. A previous study in 2021 and 2022 showed some suppression of sedges but excessive crop injury from saflufenacil as post-emergence at high rates. The study aimed to evaluate crop injury and weed efficacy from Sharpen (saflufenacil EC formulation) label rates in water-seeded rice. The 1 oz/ac and 2 oz/ac rates of Sharpen provided adequate control of the broadleaf weeds but only provide suppression over the sedges (Table 24**).** The suppression levels of sedges do not provide similar control levels to current grower standards.

Visual rice injury was observed as necrotic spots, which is typical of PPO-inhibitors, reaching up to 30% injury at 7 DAT, however, it was transient in the rice foliage. There was stand reduction from treatments compared to the standard of Butte but may be due to the Cerano application and not Sharpen (Table 5). Rice grain yield was similar across treatments (Table 24).

Table 24. Weed efficacy and rice response from Sharpen applied post-emergence in water-seeded rice, 2023 field study

			Weed control					Rice response	
Herbicide treatments	Rate	Timing	Smallflower umbrella sedge	Ricefield bulrush	Ducksalad	Redstem	Water hyssop	Rice stand count	Rice grain yield
			28 DAT				14 DAT	6 DAT	154 DAS
			%					count ft^{-2}	lbs/ac
Cerano 5 MEG	10 lb/ac	DOS	26	26	96	99	100	15	4,588
Sharpen COC	1 oz/ac	4-5 LS							
Cerano 5 MEG	10 lb/ac	DOS	41	41	98	99	100	16	5,052
Sharpen COC	2 oz/ac	4-5 LS							
Cerano 5 MEG	10 lb/ac	DOS	0	0	0	0	0	16	4,930
Butte	9 lbs/ac	1 LS	100	100	100	0	100	21	5,281
LSD α=0.05			33	32	4	1	-	2	1,298

[a]The 3-leaf stage timing was 13 days after seeding and 5-leaf stage timing was 24 days after seeding.
[b]Data were collected days after the Sharpen applications.
[c]Rice stand sampled from two areas within each plot.
[d]DAT, days after treatment; DOS, day of seeding; LSR, leaf stage rice; COC, crop oil concentrate; LSD, least significant difference.

e. Efficacy of GXP-70101 herbicide in water seeded rice

The objective of this study was to evaluate the efficacy of GWN-70101 against various target weeds (grasses, sedges & broadleaf weeds) as a part of a full season, sequential weed management program. GXP-70101 efficacy and rice crop injury were evaluated in a field trial. A randomized complete block design study with four replications was conducted at the Rice Experiment Station in Biggs, California. Twelve treatments were evaluated for weed control including: One untreated control, four GXP-70101 alone treatments, five treatments consisting of GWN-70101 as a follow up herbicide and two grower standard treatments. Partner herbicides included clomazone, penoxsulam, benzobicyclon + halosulfuron, thiobencarb, and propanil applied at their respective timing and rate stated on the label. GXP-70101 was applied at the at 4 leaf and one tiller rice stage at 0.5 liter/ac and 1 liter/ac. In the program treatments, GXP-70101 was applied at the one tiller rice stage at 0.5 liters/ac. Rice phytotoxicity was evaluated at 7, 14 and 21 days after treatment. Weed control was determined at 14, 21, 28, and 42 days after seeding. Grain yield and moisture was collected by a small plot combine. ANOVA was used to analyze data and means were separated using LSD (p=0.05). GXP-70101 provided excellent grass control at both timings and rates. Sedge control was good; however, timing was crucial. The early timing provided excellent control on ricefield bulrush but lacked control on smallflower umbrellasedge. The later timing provided greater control of smallflower umbrellasedge. Phytotoxicities were caused by base herbicides. However, rice was fully recovered, and yields were recorded for all treatments. This study demonstrated that GWN-70101 is a promising herbicide for weed control in California water-seeded rice cropping systems.

				CROP INJURY (%)								WEED CONTROL (%)												Yield
				7 DAT				28 DAT				28 DAT						42 DAT						lbs/ac
#	HERBICIDE PROGRAM	RATE/ACRE	TIMING	BLEACHING	CHLOROSIS	STUNTING	STAND REDUCTION	BLEACHING	CHLOROSIS	STUNTING	STAND REDUCTION	WATERGRASSES	SPRANGLETOP	RICEFIELD BULRUSH	SMALLFLOWER	DUCKSALAD	REDSTEM	WATERGRASSES	SPRANGLETOP	RICEFIELD BULRUSH	SMALLFLOWER	DUCKSALAD	REDSTEM	
1	UNTREATED			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3408
2	GXP-70101	0.5 L	4 LSR	0	0	0	0	0	0	0	0	98.8	99.5	94.5	28.8	67.5	21.3	99.3	100	100	30	100	45	4437
3	GXP-70101	0.5 L	1-2 TIL	2.5	2.5	1.3	0	0	0	0	0	100	100	98	90	82.5	90	100	100	100	91.3	100	85	6071
4	GXP-70101	1 L	4 LSR	0	1.3	1.3	1.3	0	0	0	0	100	100	98.3	81.3	75	55	99.5	100	100	72.5	100	62.5	5883
5	GXP-70101	1 L	1-2 TIL	3.8	5	2.5	0	0	0	0	0	100	100	98.8	94	87	83.8	99.8	100	100	97.5	100	77.5	6197
6	Cerano 5 MEG GXP-70101	12 lb 0.5 L	DOS 1-2 TIL	15	1.3	0	0	0	0	0	0	100	100	95	68.8	85	92.5	100	100	97.5	57.5	100	92.5	5504
7	Granite GR GXP-70101	15 lb 0.5 L	3 LSR 1-2 TIL	0	12.5	11.3	11.3	0	0	5	5	100	100	100	98.8	100	99.5	100	100	100	100	100	100	5875
8	Butte GXP-70101	7.5 lb 0.5 L	1.5 LSR 1-2 TIL	0	3.8	6.3	5	0	0	0	0	100	100	100	100	98.8	86.3	100	100	100	100	100	95	5573
9	Bolero Ultramax GXP-70101	23.3 lb 0.5 L	2 LSR 1-2 TIL	0	12.5	11.3	12.5	0	1.3	6.3	7.5	100	100	100	100	98.8	100	100	100	100	100	100	100	5456
10	Butte Regiment CA	7.5 lb 0.8 oz	1.5 LSR 1-2 TIL	0	11.3	11.3	11.3	0	1.3	6.3	5	99.5	100	100	100	100	67	99	100	100	100	100	62.5	6082
11	SuperWham! 80 DF GXP-70101	6 qt 0.5 L	1-2 TIL 1-2 TIL	0	7.5	5	1.3	0	0	0	0	90	97.3	100	99.5	66.3	97	90.3	100	100	100	100	100	6143
12	SuperWham! 80 DF Regiment CA	6 qt 0.8 oz	1-2 TIL 1-2 TIL	0	11.3	10	3.8	0	0	1.3	0	85.8	91.8	99.5	95.8	76.3	97.5	86.3	97.5	100	97.5	100	100	6284

GXP-70101 Nontreated control

f. Efficacy of Cliffhanger (benzobicyclon) formulations for weed control in rice

The objective of this study was to compare the weed efficacy and crop response of the 1- and 3-micron formulations of Cliffhanger (benzobicyclon) in CA water seeded rice. Benzobicyclon efficacy and rice crop injury were evaluated in a field trial. A randomized complete block design study with four replications was conducted at the Rice Experiment Station in Biggs, California. Twelve treatments were evaluated for weed control including: two untreated controls and ten standalone treatments including: Butte at 1 and 4 leaf rice at 9 lbs/ac, cliffhanger GWN-10235 formulation at 1 and 4 leaf rice at 10.3 fl oz/ac and 12.6 fl oz/ac, and cliffhanger GXP-61001 formulation at 1 and 4 leaf rice at 10.3 fl oz/ac and 12.6 fl oz/ac. Rice phytotoxicity was evaluated at 7, 14 and 21 days after treatment. Weed control was determined at 14, 21, 28, and 42 days after seeding. Grain yield and moisture was collected by a small plot combine. ANOVA was used to analyze data and means were separated using LSD (p=0.05). All Formulations provided excellent control of sedges and sprangletop in all timings and rates. Watergrass control declined with later timings and at lower rates but no significant difference among formulations were observed. All formulations performed poorly on redstem, however, GXP-61001 performed best. Phytotoxicities were higher at earlier timings and with the GXP-61001 formulation. However, rice was recovered, and yields were recorded for all treatments.

				CROP INJURY (%)								WEED CONTROL (%)												Yield
				14 DAT				28 DAT				28 DAT						56 DAT						lbs/ac
#	HERBICIDES	RATE/ACRE	TIMING	BLEACHING	CHLOROSIS	STUNTING	STAND REDUCTION	BLEACHING	CHLOROSIS	STUNTING	STAND REDUCTION	WATERGRASSES	SPRANGLETOP	RICEFIELD BULRUSH	SMALLFLOWER	DUCKSALAD	REDSTEM	WATERGRASSES	SPRANGLETOP	RICEFIELD BULRUSH	SMALLFLOWER	DUCKSALAD	REDSTEM	
1	UNTREATED 1			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2349
2	Butte	9 lbs	1 LSR	0	10	10	15	0	2.5	2.5	2.5	89.5	100	100	100	98.8	55	68	100	100	100	100	47.5	4827
3	Butte	9 lbs	4.5 LSR	0	0	0	0	0	0	0	0	38.8	91.3	100	100	87.3	43.8	10	98.8	100	100	100	0	4219
4	GWN-10235	10.3 fl oz	1 LSR	0	3.8	3.8	3.8	0	0	0	0	80	100	100	100	91.3	45	61.8	100	100	100	100	12.5	4879
5	GWN-10235	12.6 fl oz	1 LSR	0	6.3	7.5	5	0	0	1.3	2.5	90	100	100	100	96.3	51.3	76.3	100	100	100	100	25	5218
6	GWN-10235	10.3 fl oz	4.5 LSR	0	0	0	0	0	2.5	2.5	2.5	30	98.8	100	100	91.3	38.8	6.3	98.8	100	100	100	0	2173
7	GWN-10235	12.6 fl oz	4.5 LSR	0	0	0	0	0	3.8	3.8	2.5	31.3	98.8	100	100	92.5	40	1.3	100	100	100	100	0	2171
8	GXP-61001	10.3 fl oz	1 LSR	0	10	11.3	10	0	2.5	6.3	7.5	92	100	100	100	97.5	52.5	71.5	100	100	100	100	50	5145
9	GXP-61001	12.6 fl oz	1 LSR	0	10	10	13.8	0	0	6.3	6.3	83.8	100	100	100	97.5	76.3	78	100	100	100	100	66.3	5358
10	GXP-61001	10.3 fl oz	4.5 LSR	0	0	0	0	0	0	1.3	1.3	35	98.8	100	100	92.5	48.8	3.8	100	100	100	100	0	1947
11	GXP-61001	12.6 fl oz	4.5 LSR	0	0	0	0	0	3.8	2.5	2.5	46.3	98.8	100	100	92.5	46.3	16.3	100	100	100	100	15	2759
12	UNTREATED 2			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1668

g. Efficacy of Cliffhanger (benzobicyclon) applied in a program in water-seeded rice

The objective of this study is to determine the performance of Cliffhanger (benzobicyclon) season long weed management programs in CA water seeded rice. Cliffhanger efficacy and rice crop injury were evaluated in a field trial. A randomized complete block design study with four replications was conducted at the Rice Experiment Station in Biggs, California. Twelve treatments were evaluated for weed control including: two untreated controls, Butte and Cliffhanger alone and eight follow up herbicide programs consisting of Cliffhanger as a base herbicide. Partner herbicides included: pyraclonil, clomazone, penoxsulam, bispyribac, triclopyr, cyhalofop + penoxsulam and propanil applied at their respective timing and rate stated on the label. Cliffhanger was applied at 1 leaf rice & 4 leaf rice alone at 10.3 fl oz/ac. In the program treatments, Cliffhanger was applied at 1 leaf rice at 10.3 fl oz/ac. Butte was applied at 1 leaf rice at 9 lbs/ac and compared to Cliffhanger alone at 1 leaf rice. Rice phytotoxicity was evaluated at 7, 14 and 21 days after treatment. Weed control was determined at 14, 21, 28, and 42 days after seeding. Grain yield and moisture was collected by a small plot combine. ANOVA was used to analyze data and means were separated using LSD (p=0.05). Cliffhanger alone at both timings provided excellent control on sedges and sprangletop. However, watergrass control dropped significantly at the later timing. Redstem (*Ammannia spp.)* control was poor with Cliffhanger alone and some herbicide programs due to timing, exposure and weed spectrum of partner herbicides. Cliffhanger herbicide programs gave excellent control of watergrass (*Echinochloa* spp.), bearded sprangletop (*Leptochloa fascicularis*), ricefield bulrush (*Schoenoplectus mucronatus*), smallflower sedge (*Cyperus difformis)* and ducksalad (*Heteranthera limosa)*. Crop response was little to none in Cliffhanger alone treatments, slightly better than Butte alone and varied among treatments with herbicide partners. Crop phytotoxicities were mostly due to partner herbicides. However, rice recovered, and yields were recorded for all treatments. This study demonstrated that Cliffhanger is a promising herbicide for a weed control program in California water-seeded rice cropping systems.

				CROP INJURY (%)								WEED CONTROL (%)												Yield
				14 DAT				28 DAT				28 DAT						56 DAT						lbs/ac
#	HERBICIDE PROGRAM	RATE/ACRE	TIMING	BLEACHING	CHLOROSIS	STUNTING	STAND REDUCTION	BLEACHING	CHLOROSIS	STUNTING	STAND REDUCTION	WATERGRASSES	SPRANGLETOP	RICEFIELD BULRUSH	SMALLFLOWER	DUCKSALAD	REDSTEM	WATERGRASSES	SPRANGLETOP	RICEFIELD BULRUSH	SMALLFLOWER	DUCKSALAD	REDSTEM	
1	UNTREATED 1			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2536
2	Butte	9 lbs	1 LSR	0	2.5	6.3	5	0	0	0	0	94.8	100	100	100	95.8	70	94.8	100	100	100	100	58.8	5144
3	GWN-10235	10.3 fl oz	1 LSR	0	1.3	0	0	0	0	0	0	86.3	100	100	100	97.5	33.8	74.5	100	100	100	100	31.3	4980
4	GWN-10235	10.3 fl oz	5 LSR	0	0	0	0	0	0	0	0	23.8	98.3	100	100	95	26.3	2.5	92.5	100	100	100	0	3173
5	Zembu GWN-10235	14.9 lbs 10.3 fl oz	DOS 5 LSR	0	23.8	37.5	47.5	0	8.8	18.8	21.3	100	100	100	100	100	100	100	100	100	100	100	100	6284
6	Cerano 5 MEG GWN-10235	10 lb 10.3 fl oz	DOS 5 LSR	10	2.5	1.3	1.3	0	1.3	2.5	2.5	89.5	100	100	100	97.5	56.3	90.8	100	100	100	100	42.5	5569
7	GWN-10235 Granite SC	10.3 fl oz 2.5 fl oz	5 LSR 5 LSR	0	0	0	0	0	2.5	3.8	3.8	96.5	98.8	100	100	100	23.8	97	92	100	98.8	100	2.5	5374
8	GWN-10235 Regiment CA Grandstand CA	10.3 fl oz 0.8 oz 8 fl oz	1 LSR MID TIL MID TIL	0	1.3	2.5	1.3	0	3.8	7.5	2.5	89.5	98.8	100	100	100	98.8	93.5	100	100	100	100	97	5815
9	GWN-10235 Rebel X CA	10.3 fl oz 20 fl oz	1 LSR MID TIL	0	1.3	1.3	1.3	0	5	5	2.5	93.8	100	100	100	100	93.8	99	100	100	100	100	96.3	5671
10	GWN-10235 Regiment CA SuperWham! 80 DF	10.3 fl oz 0.8 oz 6 qt	1 LSR MID TIL MAX TIL	0	1.3	1.3	1.3	0	6.3	8.8	5	90	100	100	100	100	96.3	93.8	100	100	100	100	95	5455
11	GWN-10235 SuperWham! 80 DF Grandstand CA	10.3 fl oz 6 qt 8 fl oz	1 LSR MID TIL MID TIL	0	1.3	1.3	1.3	0	6.3	3.8	3.8	90.5	100	100	100	100	100	89.8	100	100	100	100	100	5266
12	UNTREATED 2			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2686

h. Clethodim (Select) herbicide application for spot treatment of Weedy rice

Spot spraying applications offer the opportunity to target specific weeds in a field, while simultaneously reducing herbicide usage and increasing the long-term efficacy of chemical control options. The studies focused on controlling California weedy rice accessions (*Oryza spp*.), and problematic grass weeds with a spot spray application of clethodim in a flooded rice system. The efficacy of incorporating nonionic surfactant (NIS) to clethodim applications was also assessed. Dose response experiments were carried out in a greenhouse on five weedy rice accessions, common grass rice weeds, and cultivated rice varieties L207, M105, M206, M209, M211, and S102 to determine the dose needed to affect these populations. Clethodim was applied in a field setting to assess spot spraying efficacy, the likelihood of dispersion which herbicide movement in the water, and crop injury.

Clethodim successfully controlled weedy rice and grasses in the greenhouse study. The effective rates to control 90% of the five test populations (ED90) were between 51 to 74 g ai ha^{-1} clethodim for weedy rice accessions. Adding nonionic surfactant to clethodim increased its efficacy by 1.6 to 1.9-fold. Cultivated rice varieties did not exhibit any tolerance to clethodim, however, spot spraying applications at 150 g ai ha^{-1} clethodim did not cause any dispersions in the field. Clethodim spot spray application was effective both at the 3 to 4 leaf growth stage and tillering growth stage for weedy rice.

The addition of NIS increased the phytotoxicity (decreased ED50 and ED90) of clethodim on weedy rice. Clethodim with NIS caused rapid plant injury that was more severe compared with plants exposed to clethodim alone. Efficacy of clethodim, assessed as 50% and 90% injury was improved 1.9 and 1.6 times by the addition of NIS, respectively. Clethodim ED50 values on average 47.5 g ai ha^{-1}, and 23.8 g ai ha^{-1} for with NIS, and without NIS. Clethodim ED90 values on average 70 50.1 g ai ha^{-1}, and 80.3 g ai ha^{-1} for with NIS, and without NIS.

All weedy rice, weedy grasses, and cultivated rice varieties responses to clethodim were different, however, a clethodim application of 80.1 g ai ha^{-1} successfully controlled all weedy rice and grasses while causing lasting injury to cultivated rice. Grass weeds differentially responded to clethodim at increasing rates. Clethodim ED50 ranged from 19.77 to 48.47 g ai ha^{-1} with ranging of *Leptochloa fusca* > *Echinochloa oryzoides* > *Echinochloa oryzicola* > *Echinochloa cruss-galli* > and *Echinochloa colona*. ED90 ranged from 42.9 and 80.1 g ai ha^{-1} with ranging *Leptochloa fusca* > *Echinochloa oryzoides* > *Echinochloa colona* > *Echinochloa oryzicola* > and *Echinochloa cruss-galli*.

Clethodim migration within and around the application area was investigated. Rates of 150 and 300 g ai ha^{-1} clethodim killed weeds and rice within the original 100 by 50 cm application area. There were slight differences between the first and second locations where the study was conducted. In the first location, 150 g ai ha^{-1} clethodim caused 93% rice injury when applied at the 3 to 4 leaf stage. The clethodim spot sprays caused 89% rice injury at the application point when applied at tillering stage. The 300 g ai ha^{-1} clethodim was not applied at 3 to 4 leaf stage, however, it caused 93% injury when applied at tillering stage. In the second location, 150 g ai ha-1 clethodim caused 97% rice injury when applied at the 3 to 4 leaf stage. The clethodim spot sprays applied at the tillering stage caused 73% rice injury. The 300 g ai ha^{-1} clethodim was not applied at 3 to 4 leaf stage, however, 300 g ai ha^{-1} clethodim caused 83% rice injury when sprayed at the tillering stage. Clethodim rates of 0, 9.4, 18.8, 37.5, 75, and 150 g ai ha^{-1} had no dispersion or injury in the first (0 to 25cm), second (25 to 50cm), or third (50 to 75cm) dispersion are. The 300 g ai ha^{-1} clethodim showed dispersion up to 25 cm from the application point and 10% injury in the first dispersion area, but no injury in the second or third dispersion area. The 600 g ai ha^{-1} clethodim rate showed dispersion until 40 cm with 100% injury in the first dispersion area, 40% injury in the second dispersion area, and no injury in the third dispersion area. The 1200 g ai ha^{-1} rate showed dispersion up to 55 cm, with 100% injury in both the first and second dispersion areas, and 10% injury in the third dispersion area. The 2400 g ai ha^{-1} rate demonstrated that clethodim could migrate out to 75 cm away from the original application point with 100% injury in the first, second, and third dispersion areas.

i. Evaluation of WE-2058-1 and WE-2055-1 in California Water-Seeded Rice

WE-2055-1 (*Kaolin*) and WE-2058-1 (*Ethylene Glycol*) were evaluated at different rates, sometimes in combination with other herbicides. The objective of this study was to determine weed control, crop safety of optimum use rate and application timing of WE-2055-1 and WE-2058-1 in California rice, measure efficacy of each treatment compared to the untreated checks for all weed species present, compare efficacy of all granule treatments, and to measure the efficacy of WE2055-1 and WE2058-1 when combined with tank mix of propanil and regiment. Copper sulfate was applied at 10 lb/ac for algae control.

The treatments for this study included WE-2058-1 19.5 lb/a at 2 LSR, WE-2055-1 11.5 lb/A at 2 LSR, WE-2055-1 14.4 lb/a at 2 LSR, WE-2055-1 17.2 lb/A at 2 LSR, WE-2055-1 34.4 lb/A at 2 LSR, WE-2055-1 11.5 lb/A at 2 LSR followed by Regiment 0.8 oz/A and Dyne-amic 5 fl oz/A applied at 5 LSR and SuperWham 6 qt/A, WE-2055-1 at 14.4 lb/A at 2 LSR followed by Regiment 0.8 oz/A and Dyne-amic 5 fl oz/a applied at 5 LSR and SuperWham 6 qt/A and SS MSO 1.5 pt/A applied at max-till, WE-2055-1 at 17.2 lb/A at 2 LSR followed by Regiment 0.8 oz/A and Dyne-amic 5 fl oz/A applied at 5 LSR and SuperWham 6 qt/A and SS MSO 1.5 pt/A applied at max-till, and WE-2055-1 at 11.5 lb/A with WE-2058-1 at a rate of 19.5 lb/A at 2 LSR followed by Regiment 0.8 oz/A and Dyne-amic 5 fl oz/a applied at 5 LSR and SuperWham 6 qt/A and SS MSO 1.5 pt/A applied at max-till.

All treatments in this study proved effective weed control. At 14 DAT, all treatments gave effective control of water grasses. The treatment that provided the best over-all weed control was the WE-2055-1 at 17.2 lb/a in conjunction with other herbicides following its application. This remains the best at weed control even up to 42 DAT. The standalone treatment of WE-2055-1 at 34.4 lb/a also gave excellent weeds control.
At the 7 DAT rating, appeared bleached and with some stand reduction. This is most prevalent in the standalone application of WE-2055-1 with a rate of 34.4 lb/a as these plots have the highest presence of bleaching and stunning at this point. Other treatments caused high level of crop bleaching as well, including standalone treatment of 17.7 lb/a with high amounts of bleaching at 7 DAT and the treatments of WE-2055-1 and WE-2058-1 that are applied in conjunction with other herbicides. However, most of the crop rice would gone away by 28 DAT.

The treatment that gave the highest yield was WE-2055-1 at 14.4 lb/a in conjunction with Propanil and Regiment, with a yield of 6207 lb/A. The untreated control gave the lowest yield at 3029 lb/A. In summary, both WE2055-1 and WE2058-1 appear to be promising, evenly matched herbicides for weed control in California rice. Despite its effectiveness in weed control, the standalone application of WE-2055-1 at 34.4. lb/ac causes a significant crop bleaching symptoms to the rice. The treatments of WE-2055-1 at 17.2 lb/and WE-2055-1 at 14.4 lb/a in conjunction with other herbicides, both look the most promising when taking weed control, crop damage and yield into consideration.

j. Impact of simulated drift rates of Cliffhanger, GXP-70101, and tetflupyrolimet on non-target crops.

The study was conducted at UC Davis in almond, peach, prune, pistachio, and walnut orchards planted on March 3, 2020, and an established vineyard in west Davis, CA. Most rice herbicides are applied in the

Sacramento Valley from late May to early July. Therefore, to simulate growth stages and environmental conditions, trees and vines in these experiments were subjected to simulated drift rate treatments on May 31, 2023.GPX-7010, Cliffhanger, and tetflupyrolimet were applied at four rates resembling a plausible drift rate: 0.5, 1, 3, and 10%, where the fractional rates were based on use rates in rice (Table 25). Experiments were conducted as a randomized complete block with four replicates; experimental units were single trees and vines, and each species was considered a separate experiment. Herbicides were applied from the top to the ground on one side of the canopy. A handheld, CO_2-pressurized two nozzle spray boom with XR8004(AI) nozzles at 40 PSI pressure delivers 0.40 GPM was used. All herbicide treatments were delivered by the same person for consistency in the study.

Visual injury ratings and symptom evaluations were done at 24, 48, and 72 hours, as well as at 7, 14, 21, 28, 35, 42, 60, and 90 days after herbicide applications. Injury ratings based on a scale where 0 means no injury and 100 means plant death. Photos of trees and leaves were taken from the same side, distance, and perspective at each injury rating time. None of the simulated Cliffhanger, GXP-70101, and tetflupyrolimet drift rates caused a detectable injury during the 2023 growing season. In addition, tree trunk diameters were not reduced in all tested species. Furthermore, no yield reduction was observed with all herbicides on grape. This research suggests that Cliffhanger, GXP-70101, and tetflupyrolimet drift would not have on injury nontarget plants included in this study. Stewardship plans for GXP-70101, Cliffhanger, and tetflupyrolimet herbicides based on the off-target drift experiments are very important for our knowledge and the possible use of Cliffhanger, GXP-70101, and tetflupyrolimet in the weed management of orchard and vineyard crops. We will follow up in the spring of 2024 and investigating the visual injury ratings to predict the residual injury.

Table 11. Herbicide Treatments.

Treatment No	Treatment Description	Rate	Rate Unit	Alt Rate	Use Rate	Use Rate Unit
1	untreated check	0	-	0	0	-
2	Cliffhanger	1.5	g ai/ha	1/200X	300	g ai/ha
3	Cliffhanger	3	g ai/ha	1/100X	300	g ai/ha
4	Cliffhanger	9	g ai/ha	1/33X	300	g ai/ha
5	Cliffhanger	30	g ai/ha	1/10X	300	g ai/ha
6	GXP-70101	0.625	g ai/ha	1/200X	125	g ai/ha
7	GXP-70101	1.25	g ai/ha	1/100X	125	g ai/ha
8	GXP-70101	3.75	g ai/ha	1/33X	125	g ai/ha
9	GXP-70101	12.5	g ai/ha	1/10X	125	g ai/ha
10	Tetflupyrolimet	0.625	g ai/ha	1/200X	125	g ai/ha
11	Tetflupyrolimet	1.25	g ai/ha	1/100X	125	g ai/ha
12	Tetflupyrolimet	3.75	g ai/ha	1/33X	125	g ai/ha
13	Tetflupyrolimet	12.5	g ai/ha	1/10X	125	g ai/ha

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

a. Utilizing germinability thresholds for optimizing stale seedbed applications to control red rice (*Oryza* spp.) in California rice cropping systems

Weedy" red rice is a problematic weed with phenotypic similarities to cultivated rice. Limited herbicide availability has driven a need for nonchemical control options for managing this pest. One preplanting strategy that is being explored is the stale seedbed methodology, which aims to maximize soil seedbank withdrawals via germination. This technique is adapted in rice by flooding a field, waiting for germination and emergence of weed seedlings, and completing the method with a mechanical or chemical control application. Optimization of this process is dependent on maximizing weed seed germination, which is primarily influenced by both temperature and moisture availability. Germinability across a range of these factors is not well understood in California red rice. Thus, this study was aimed to determine germinability of California red rice accessions under various temperature and water potential treatments. Previously described red rice accessions 1, 2, 3, and 5, along with 'M206', a common California rice cultivar, were exposed to temperatures from 10 to 40 C in combination with water potentials of 0, −0.2, −0.4, or −0.8 MPa until either germination or weed seed decay occurred. Statistical analysis indicated a three-way interaction between accession, temperature, and water potential. Germination reached 95% when seeds were exposed to temperatures from 20 to 35 C in combination with 0 or −0.2MPa. Germination was lowest when seeds were water stressed (−0.8 MPa) and when temperatures were colder than 20 C or warmer than 35 C. The 'M206' cultivar was utilized for comparison and demonstrated cold tolerance by germinating at 10 C, whereas weedy accessions 1, 2, and 3 did not. When temperatures were at or above 15 C, however, 'M206' germinated less often compared with all weedy accessions. Historical preplant temperatures in this region align with those required for weedy rice germination, thus the stale seedbed methodology is a viable strategy in years when ample floodwater is available.

b. Assessment of anaerobic germination potential in California weedy rice (*Oryza sativa spontanea*) accessions

Weedy rice is a common and problematic pest in California rice production, and control can be difficult because of similarities between weedy rice and cultivated rice. Anaerobic conditions are often present in rice fields due to flooding of soil, and previous research alludes to anaerobic germination of some weedy rice accessions. This study aims to determine if certain accessions of weedy rice are capable of successful anaerobic germination. If anaerobic sensitivity is found, pest management practices can be developed accordingly to control weedy rice in commercial rice fields. The study was conducted on California weedy rice accessions 1, 2, 3, 5, and cultivar M206. Seeds of each accession were placed in 1"x 1"x 2" plug trays and buried at a depth of 0.5 inches in soil. The plug trays were nested in larger plastic tubs and flooded to 6 inches for anaerobic replicates, and 0.5 inches for aerobic replicates. Tubs were then placed into a dark growth chamber at 86F for fourteen days. Seeds were harvested from the trays, total number of seeds germinated for each accession were counted, and coleoptile and radicle lengths of each germinated seed were recorded. Data illustrated that weedy accessions 3 and 5 were capable of germination in anaerobic conditions, while accessions 1 and 2 were not. Further research is required to confirm these results and the assumptions that certain California weedy rice accessions would germinate anaerobically.

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. Diagnostic and detection of herbicide resistance in Farmers' fields

For seeds collected from 2022 growing season, testing of suspected herbicide resistant weeds was conducted on 44 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 herbicide but also to give growers herbicide options in case they have resistance in their fields. For 2022, we have tested 1, 16, 5, 4, 25, 18, and 1 samples of ricefield bulrush, smallflower umbrella sedge, late watergrass, early watergrass, barnyardgrass, breaded sprangletop and redstem. Most of the sample tested showed resistance to at least one herbicide. We had several 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 resistant weed. The summary of results is in Table 26.

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 tested all herbicides that are recommended to control the weed. The protocol is similar to 2022 protocol. Growers/PCA(s) received reports that not only show if the weed is resistance to particular herbicide(s) but also provided herbicide alternatives for controlling of this 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. Results of the survey showed several weed populations with multiple and cross resistance to different mode of action herbicide. Fortunately, the survey results help growers to select herbicides that control these resistant biotypes (Table 26).

Table 26. Number of Observed Herbicide Resistance from 2020-2021 Herbicide Resistant Screening Samples

Weed Species[1] [Total number received]	Herbicides								
	Bolero	Butte	Cerano	Clincher	Grandstand	Granite SC	Propanil	Regiment	Loyant
	--			Number of resistant samples			---------------------------------------		
Barnyardgrass [25]	3	4	2	5			0	0	5
Early watergrass [4]	1	0	0	1			3	3	1
Late watergrass [5]	1	2	1	1			2	2	2
Bearded Sprangletop [18]	1	3	1	4					7
Smallflower Umbrella Sedge [16]	2	1			1	4	7	5	0
Redstem [1]					1	0	1	1	

b. Target site mechanism confers resistance pattern of ACCase-inhibitors in bearded sprangletop from California

In California rice fields, sprangletop is a competitive annual semiaquatic grass that is frequently present in most rice fields. Bearded sprangletop produces large number of seeds and generally seedlings emerged later than other weedy grasses. Bearded sprangletop can reduce rice grain yield by up to 36% if it is not controlled. While flooding rice field with deep water is a common practice to suppress bearded sprangletop, herbicides are a major component of California's weed-control strategy to achieve adequate bearded sprangletop control and high rice yields. Despite using integrated weed management methods, bearded sprangletop biotypes in California have been suspected to be resistant to herbicides such as cyhalofop (acetyl-CoA carboxylase, ACCase, inhibitor), thiobencarb (group 15, very long chain fatty acid elongases inhibitor, VLCFA), clomazone (group 13, 1-deoxy-d-xyulose 5-phosphate synthase inhibitor), benzobicyclon + halosulfuron-methyl (group 27, 7, 4-hydroxyphenylpyruvate dioxygenase, HPPD + group 2, acetolactate synthase inhibitor, ALS) . Only clomazone resistance has been confirmed in bearded sprangletop biotypes. Preliminary studies suggested target site resistance to cyhalofop by bearded sprangletop. Currently, there are relatively few herbicides that can control bearded sprangletop. Therefore, identification of the mechanisms of resistance are important to help developing management strategies to control and delay resistance development in bearded sprangletop.

Bearded sprangletop biotypes have been suggested to have developed herbicide resistance to Acetyl-CoA carboxylase (ACCase) such as cyhalofop-P-butyl (cyhalofop) as a result of the frequent and widespread use of

ACCase-inhibiting herbicides. The aim of this study was to evaluate suspected resistant bearded sprangletop biotypes, R1, R2, R3, and the susceptible biotype, S1, in terms of their levels of resistance to three ACCase-inhibiting herbicides and to characterize the molecular mechanisms of resistance. Dose-response experiments suggested that the biotype R1, R2, and R3 had high-level resistance to cyhalofop, and quizalofop-P-ethyl (quizalofop), but not clethodim. Target-site mechanism was identified that resistance to ACCase inhibitors is due to the nucleotide substitution. The carboxyl transferase (CT) domain of the ACCase gene's sequence analysis revealed the substitutions Trp-2027-Cys for R1 and R2 biotypes and Ile-2041-Asn for R3 biotype. This study revealed that presence of target-site resistance to cyhalofop and quizalofop in at least two mutation points in representative biotypes of bearded sprangletop in California. This research highlights the significance of careful herbicide selection, crop rotation, and field reconnaissance to help managing bearded sprangletop in rice field.

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GENERAL SUMMARY OF CURRENT YEARS RESULTS

- Research was conducted to develop effective weed management programs in two rice cropping systems including continuous flooded rice and partially flooded rice (pinpoint). 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. We have conducted research to determine the potential to incorporate new herbicides to manage weeds including herbicide resistant weeds. Our field research showed that Loyant has a broad-spectrum weed control activity. Loyant has good control of sedges and broadleaf weeds and provide suppression of grasses. Our research showed that Loyant is a good clean up herbicide, but it needs to be tank mix with other herbicides such as propanil, Clincher, Granite, or Regiment. Our research also showed that Loyant can be used to control Cattail that is spreading in several rice fields especial the Delta area. One application of 1.33 pint per acre was enough to kill 3 ft tall cattail plants. For 6 ft tall plants, two applications of Loyant were needed to control cattail.

- Zembu (Pyraclonil 1.8%was minimal) is a new herbicide that was approved by EPA. Zembu is a useful tool to suppress grasses and control sedges and broadleaf weeds. However, it has poor activity on breaded sprangletop and ricefield bulrush. Zembu can be applied at day of seeding, however, our research showed that combination of Zembu and Cerano at 8 lb per acre can be a used to control grasses, sedges, and broadleaf weeds. Zembu may cause slight stunting early on, but rice plants recovered from stunting with no yield penalty. Furthermore, our research showed that Zembu would an excellent herbicide to control herbicide resistant weeds. We have also studied the efficacy of Zembu applied in rice field at different water management systems. The research showed excellent efficacy regardless of water management system in the field.

- We also conducted advance testing for the new grass herbicide from FMC, tetflupyrolimet that has a novel mode of action. Tetflupyrolimet provided outstand control of barnyardgrass, early watergrass, late Watergrass, and breaded sprangletop when applied at day of seeding or at early postemergence. We studied California varietal response to tetflupyrolimet and found it is safe on all tested rice verities. We also found that the combinations of tetflupyrolimet with other postemergence herbicide do not cause any antagonistic effect of weed control. Furthermore, our research showed that this herbicide can be an outstanding tool to control herbicide resistance weeds.

- We have conducted research to determine the efficacy of ALB2023 for use in ROXY Rice Production System® and ROXY trait rice for weed control and crop safety. Roxy rice, a new technology developed at the California Rice Experiment Station. This rice is resistance to oxyfluorfen (ALB 2023). The research showed that Roxy rice is a promising technology. ALB2023 applied at different rates were safe on rice with excellent control of most grasses and broadleaf weeds. ALB2023, however, showed poor control of ricefield bulrush but the addition of other herbicides to ALB2023 would effectively control ricefield bulrush.

- Cliffhanger (benzobicyclon) will be available to rice growers in the next growing season. California rice growers have good results with using Butt herbicide which is benzobicyclon + halosulfuron. Cliffhanger would provide flexibility to use, compare to Butte because it does not have strong crop rotation restrictions. We have conducted research to compare the efficacy of Cliffhanger with Butte. Our research should that Cliffhanger provided similar efficacy to Butte application. Weed control and crop safety will be similar with both herbicides.

- We have conducted intensive research to explore the possibility to use spot treatment of clethodim to control weedy rice in rice field. Clethodim successfully controlled weedy rice and grasses in rice field. The effective rates to control 90% of the five test weedy rice populations were between 0.75 to 1.1 oz ai per acre. Adding nonionic surfactant to clethodim increased its efficacy by 1.6 to 1.9-fold. Cultivated rice varieties did not exhibit any tolerance to clethodim, however, spot spraying applications at 2.25 oz ai per acre clethodim did not cause any dispersions in the field. Clethodim spot spray application was effective both at the 3 to 4 leaf growth stage and tillering growth stage for weedy rice. Clethodim migration within and around the application area was investigated. Rates of 2.25 and 4.5 oz ai/A clethodim killed weeds and rice within the original 100 by 50 cm application area. The 9 oz ai/A clethodim rate showed dispersion until 13 inches with 100% injury in the first dispersion area, 40% injury in the second dispersion area, and no injury in the third dispersion area. The 26 oz/A rate showed dispersion up to 18 inches, with 100% injury in both the first and second dispersion areas, and 10% injury in the third dispersion area. The 36 oz ai/A rate demonstrated that clethodim could migrate out to 28 inches away from the original application point with 100% injury in the first, second, and third dispersion areas.

- We continue to work to use pendimethalin on water seeded rice to control grasses. Our research showed the potential of using specific formulations of pendimethalin at 3 to 5 rice leaf stage. We also found that pendimethalin can be very useful tool to control weeds in rice when applied after leathering. However, a combination of pendimethalin with Clincher, propanil, and Regiment need to be used to control emerged grasses. The use of pendimethalin after leathering would provide outstanding control of late emerging grasses.

- We have an active research program to evaluate several new herbicides in water seeded rice. In 2023 we tested several new herbicides for water-seeded rice, including GXP-70101, saflufenacil, WE2058, and WE2055. We will continue our research to fine tone the use of these herbicides in California water-seeded rice.

- We have conducted simulated herbicide drift rate studies to evaluate if herbicide drift of Loyant, Cliffhanger, or GXP-70101 can cause damage to prune, peaches, almond, pistachio, walnut, and grape. Result showed that herbicide drift of Loyant, Cliffhanger, or GXP-70101 were insignificant on these crops. We will continue our effort to study if there is a long-term effect of these herbicide on tree and nut fruits and vines.

- Weedy” red rice is a problematic weed with phenotypic similarities to cultivated rice. Limited herbicide availability has driven a need for nonchemical control options for managing this pest. One preplanting strategy that is being explored is the stale seedbed methodology, which aims to maximize soil seedbank withdrawals via germination. This technique is adapted in rice by flooding a field, waiting for germination and emergence of weed seedlings, and completing the method with a mechanical or chemical control application. Optimization of this process is dependent on maximizing weed seed germination, which is primarily influenced by both temperature and moisture availability. Germinability across a range of these factors is not well understood in California red rice. Thus, our research was aimed to determine germinability of California red rice accessions under various temperature and water potential treatments. Previously described red rice accessions 1, 2, 3, and 5, along with 'M206', a common California rice cultivar, were exposed to temperatures from 10 to 40 C in combination with water potentials of 0, −0.2, −0.4, or −0.8 MPa until either germination or weed seed decay occurred. Germination reached 95% when seeds were exposed to temperatures from 20 to 35 C in combination with 0 or −0.2MPa. Germination was lowest when seeds were water stressed (−0.8 MPa) and when temperatures were colder than 20 C or warmer than 35 C. The 'M206' cultivar was utilized for comparison and demonstrated cold tolerance by germinating at 10 C, whereas weedy accessions 1, 2, and 3 did not. When temperatures were at or above 15 C, however, 'M206' germinated less often compared with all weedy accessions. Historical preplant temperatures in this region align with those required for weedy rice germination; thus, the stale seedbed methodology is a viable strategy in years when ample floodwater is available.

- We have tested more than 69 samples of suspected herbicide resistant weed populations that were collected by growers and PCA including barnyardgrass, early and late watergrass, smallflower umbrella sedges, sprangletop, and ricefield bulrush. 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 2023, both our field and lab program seek 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.

- Bearded sprangletop biotypes have been suggested to have developed herbicide resistance to Acetyl-CoA carboxylase (ACCase) such as cyhalofop-P-butyl (cyhalofop) because of the frequent and widespread use of ACCase-inhibiting herbicides. We evaluated suspected resistant bearded sprangletop biotypes, R1, R2, R3, and the susceptible biotype, S1, in terms of their levels of resistance to three ACCase-inhibiting herbicides and to characterize the molecular mechanisms of resistance. Dose-response experiments suggested that the biotype R1, R2, and R3 had high-level resistance to cyhalofop, and quizalofop-P-ethyl (quizalofop), but not clethodim. Target-site mechanism was identified that resistance to ACCase inhibitors is due to the nucleotide substitution. The carboxyl transferase (CT) domain of the ACCase gene's sequence analysis revealed the substitutions Trp-2027-Cys for R1 and R2 biotypes and Ile-2041-Asn for R3 biotype. This study revealed that presence of target-site resistance to cyhalofop and quizalofop in at least two mutation points in representative biotypes of bearded sprangletop in California. This research highlights the significance of careful herbicide selection, crop rotation, and field reconnaissance to help managing bearded sprangletop in rice field.