Spread and management of herbicide resistant weeds in California rice

Kassim Al-Khatib

University of California

Davis

Chemical Weed Management

Challenging, Complex, Expensive, and Regulated

Sequential herbicide treatments in continuous flood system rice

Treatment [a]	Rate (per acre)	Timing
Untreated control	-	-
Cerano	12 lb	DOS
Cerano fb SuperWham +COC	12 lb fb 6qt + 0.125%	DOS fb 1-2 tiller
Cerano fb Abolish + Regiment +NIS + UAN	12 lb fb 1.5 qt + 0.67 oz +0.25% + 2.0%	DOS fb 5 lsr
Cerano fb Shark H2O fb Granite SC + COC	12 lb fb 8 oz fb 2.8 oz + 2.5%	DOS fb 1 lst fb 5 lsr
Cerano fb Shark H2O fb Abolish + Regiment + NIS +UAN	9 lb fb 8oz fb 1.5 qt + 0.67 oz +0.25% +2.0%	DOS fb 1 lst fb 5 lsr
Cerano fb Butte	12 lb fb 7.5 lb	DOS fb 1 lsr
Granite GR	15 lb	3 lsr
Granite GR fb SuperWham + COC	15 lb fb 6 qt + 2.5%	3 lsr fb 1-2 tiller
Granite SC + COC fb SuperWham + COC	2.8 oz + 2.5% fb 6 qt + 2.5%	3 lsr fb 1-2 tiller
Granite GR fb RiceEdge + COC	15 lb fb 10 lb + 2.5%	3 lsr fb 1-2 tiller
Granite GR fb Abolish + Regiment +NIS + UAN	15 lb fb 1.5 qt + 0.67 oz +0.25% + 2.0%	3 lsr fb 1-2 tiller
League MVP	35 lb	2 lsr
League MVP fb SuperWham + COC	35 lb fb 6 qt + 2.5%	2 lsr fb 1-2 tiller
Bolero fb SuperWham + COC	23 lb fb 6 qt + 2.5%	2 lsr fb 1-2 tiller
Bolero fb Regiment +NIS + UAN	23 lb fb 0.67 oz +0.25% + 2.0%	2 lsr fb 5 lsr
Bolero fb Regiment +NIS + UAN fb SuperWham + COC	23 lb fb 0.67 oz +0.25% + 2.0% fb 6 qt + 2.5%	2 lsr fb 5 lsr fb 1-2 tiller
Abolish + Regiment +NIS + UAN	1.5 qt + 0.67 oz +0.25% + 2.0%	5 lsr
Abolish + Regiment +NIS + UAN fb SuperWham	1.5 qt + 0.67 oz +0.25% + 2.0% fb 6 qt + 2.5%	5 lsr fb 1-2 tiller

Percent Weed control 60 DAS as affected by herbicide treatments

Treatment	Late watergrass	Sprangletop	Ricefield Bulrush	Smallflower sedge	Ducksalad
Cerano	91	100	0	0	98
Cerano + SuperWham	98	100	88	76	97
Cerano + Abolish + Regiment	100	100	88	70	98
Cerano + Shark + Granite	100	100	94	87	100
Cerano + Shark + Abolish + Regiment	100	100	92	88	100
Cerano + Butte	99	100	100	100	100
Granite	99	28	100	98	100
Granit GR + SuperWham	98	35	100	100	100
Granit SC + SuperWham	98	35	100	97	95
Granite + RiceEdge	100	39	100	100	100
Granite + Abolish + Regiment	99	73	100	100	100
League MVP	96	100	100	100	100
League MVP + SuperWham	97	100	100	100	100
Bolero + SuperWham	90	100	100	100	98
Bolero + Regiment	94	100	100	100	100
Abolish + Regiment	98	100	100	100	99
Bolero + Regiment + SuperWham	95	90	95	82	94
Untreated control	0	0	0	0	0

Percent rice plants injury 40 DAS and yield as affected by herbicide treatments

Treatment	Bleaching	Stunting
Cerano	0	20
Cerano + SuperWham	0	20
Cerano + Abolish + Regiment	0	27
Cerano + Shark + Granite	0	3
Cerano + Shark + Abolish + Regiment	0	10
Cerano + Butte	0	25
Granite	0	3
Granit GR + SuperWham	0	8
Granit SC + SuperWham	0	5
Granite + RiceEdge	0	10
Granite + Abolish + Regiment	0	10
League MVP	0	10
League MVP + SuperWham	0	7
Bolero + SuperWham	0	1
Bolero + Regiment	0	5
Abolish + Regiment	0	5
Bolero + Regiment + SuperWham	0	20
Untreated control	0	5

Weed control in California rice

- Herbicide applied multiple times during the growing season
- Herbicide used for consecutive seasons; OR repeated application with same site of action
- No crop rotation
- No other weed control practices
- Herbicides are costly so growers cutting the rate

Topics to cover…

- Herbicide resistance, diagnosis and early response
- Finding new modes of action
- Understanding the molecular base of herbicide resistance for target management
- Direct seeded rice

2011 Resistance Testing

Weed species	# Samples	Propanil	Bensulfuron	Clomazone	Cyhalofop	Penoxulam
Bulrush	8	3	3	-	-	1
Smallflower	8	4	3	-	-	-
Watergrass	6	0	-	-	-	-
Sprangletop	9	-	-	3	1	-
Total	31					

2015 Resistance Testing

Weed	Herbicides
Echinochloa species complex	Thiobencarb, Cerano, Clincher, Propanil, Londax, Regiment, and Granite
Smallflower umbrella sedge	Thiobencarb, Propanil, Londax, Regiment, Granite, and Shark
Ricefield Bulrush	Propanil, Londax, Regiment, Granite, Shark, and Grandstand
Redstem	Londax, Granite, and Grandstand
Sprangletop	Thiobencarb, Cerano, and Clincher

HERBICIDE RESISTANCE TESTING FORM RFBR-15-04

Name of weed: Ricefield bulrush

Date of collection:

Submittee Information:

Name:

Email:

Phone #:

Grower Information:

Name:

Address:

Phone #:

Field/Site Information:

GPS Coordinates:

Township:

Nearest Road:

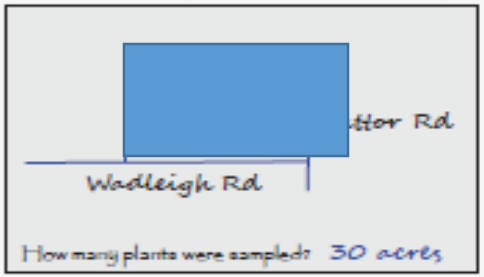
Size of the field: 320 acres

Percentage of field that is suspected to be resistant: 5%

When was the resistance suspected in this field: 2013

Please mark the tentative location of the field on the map

Please draw a brief map of field with location of sampling



How many plants were sampled? 30 acres

	Herbicides used: In the past	Herbicides used: This year	Resistance: Known	Resistance: Suspected	Test result X= Resistant (This is for our purposes, lab is in bold)
Abolish 8 E.C	☐	☐	☐	☐	☐
Bolero (Thiopta)	☐	☐	☐	☐	☐
Cargin 5 ME.G	☐	☒	☐	☐	☐
Clincher CA	☒	☐	☐	☐	☐
Grandstand CA	☐	☒	☐	☒	☐
Granite GR	☐	☒	☐	☒	☐
Granite SC	☐	☐	☐	☒	☐
Halomax	☐	☐	☐	☐	☐
Laggia MVP	☐	☐	☐	☐	☐
Londax	☒	☐	☐	☐	☐
Regiment CA	☐	☐	☐	☐	☐
RiceEdge 60 DF	☐	☐	☐	☐	☐
Rinshot 48 E.C	☐	☐	☐	☐	☐
Sandea	☐	☐	☐	☐	☐
Shark H2O	☐	☐	☐	☐	☐
Stam 80 EDF CA	☐	☐	☐	☐	☐
Strada CA	☒	☐	☐	☐	☒
SuperWham CA	☐	☒	☐	☒	☐
Other	☐	☐	☐	☐	☐

Water Management

Source(s) of water:

- ☐ Pump
- ☐ Canal
- ☐ Both

Irrigation management:

- ☐ Continuous flood
- ☐ Pinpoint
- ☐ Leaching method

Was water compromised or lost at any time of the season? ☐ Yes ☐ No

Bring the sample and form to your local UCCE Farm Advisor or drop off samples at the address below preferably at the end of September.

Rice Experiment Station | 955 Butte City Hwy (162) | PO Box 306 | Biggs CA 95917

University of California Rice Weed Research Program

Report: 2015 Herbicide Resistance Testing

Sample reference #: RFBR-15-01

Resistance status to the herbicides TESTED	Comments on the herbicides NOT TESTED
Grandstand [No]	**Halomax** - As your sample is susceptible to Granite SC and Strada (other ALS inhibitor herbicides), it is highly likely that your sample also susceptible to Halomax.
Shark H2O [No]	**Regiment** - This herbicide is labeled for partial control or suppression of riceflield bulrush. As your sample is susceptible to Granite SC and Strada CR, there is a high chance that your sample is also susceptible to this ALS inhibitor herbicide. However, do not rely exclusively on this herbicide for controlling your riceflield bulrush.
Propanil [No]	**RiceEdge** (propanil + halosulfuron) - See the comment for Halomax. Even if your sample is resistant to Halomax, this herbicide is STILL an option.
Granite SC [No]	**Granite GR** - Your sample should be susceptible to Granite GR (penoxsulam). Granular formulation of penoxsulam (Granite GR) may be less effective than the liquid formulation (Granite SC)
Strada CR [No]	
[Yes] Your sample is RESISTANT to this herbicide.	
[No] Your sample is SUSCEPTIBLE to this herbicide.	

NOTES:

Enclosed are:

- 2016 CALIFORNIA RICE WEED HERBICIDE SUSCEPTIBILITY CHART
- HW HERBICIDE OPTIONS CHART
- HERBICIDE RESISTANCE TESTING FORM (for 2016 season)

Feel free to ask questions regarding your sample. Please use the sample reference # for inquiries.

General Principles of Herbicide Resistance Management

- Apply integrated weed management practices. Use multiple herbicide sites of action with overlapping weed spectrums in rotation, sequences, or mixtures.
- Use the full recommended herbicide rate and proper application timing for the targeted to control weed species present in the field.
- Scout fields after herbicide application to ensure control has been achieved. Avoid allowing weeds to reproduce by seed or by possible vegetatively.
- Monitor site and clean equipment between sites.

Source: California Rice Research Board

Contact:

Brian Dodar
UC Rice Weed Research Program
Rice Experiment Station, Biggs
[illegible]
[illegible]

or

Nilesh M. Khatib
Professor of Weed Physiology
University of California, Davis
[illegible]
[illegible]

Visit http://rice.ucanr.edu for updated information about rice weed control, herbicide resistance management, and other relevant educational materials.


RFBR-15-HR
Untreated
Grandstand
Shark H2O
Granite SC
Propanil
Strada CA


RFBR-15-01
Untreated
Grandstand
Shark H2O
Propanil
Strada CA
Granite SC

Resistance status to the herbicides TESTED

Grandstand **No**

Shark H_2O **No**

Propanil **Yes**

Granite SC **No**

Strada CA **Yes**

Yes Your sample is RESISTANT to this herbicide.

No Your sample is SUSCEPTIBLE to this herbicide.

Comments on the herbicides NOT TESTED

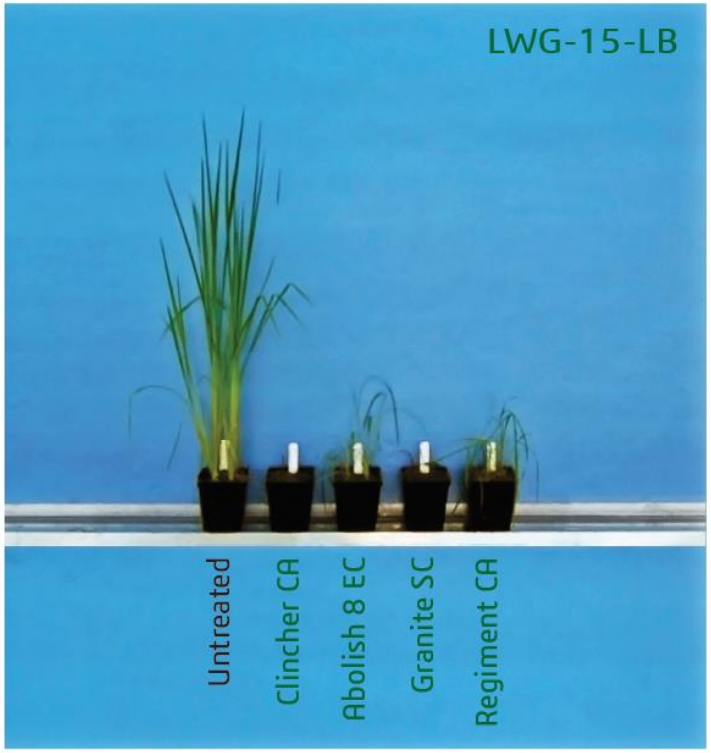
Halomax = As your sample is resistant to Strada CA (other ALS-inhibitor herbicides), it is likely that your sample also resistsant to Halomax.

Regiment = This herbicide is labeled for partial control or suppression of ricefield bulrush. As your sample is resistant to Strada CA, there is a a fair chance that your sample is also resistant to this ALS-inhibitor herbicide. In any case, do not rely exclusively on this herbicide for controlling your ricefield bulrush.

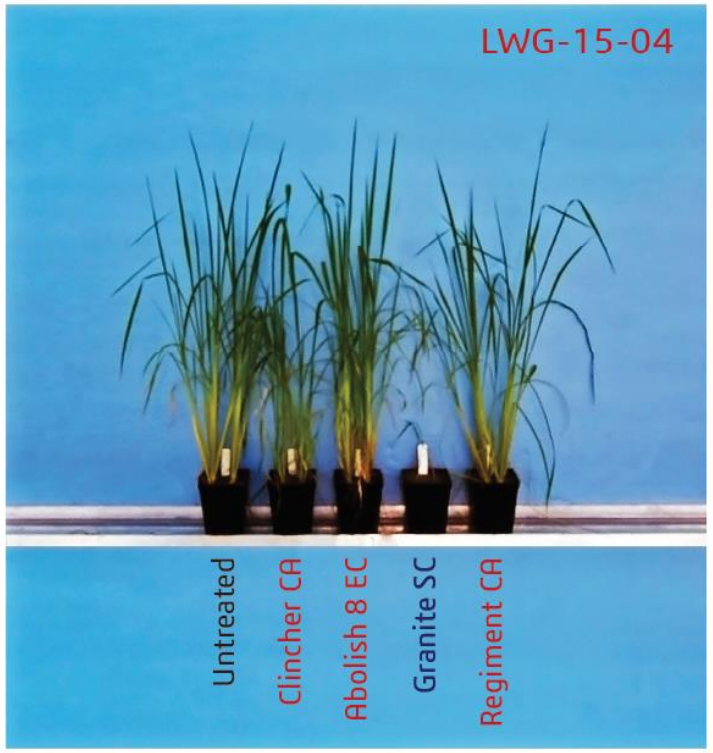
RiceEdge (propanil + halosulfuron) = See the comment for Halomax. If your sample is susceptible to Halomax, then this herbicide is STILL an option.

Granite GR = Your sample should be susceptible to Granite GR (penoxulam). Granular formulation of penoxulam (Granite GR) may be less effective than the liuid formulation (Granite SC).

Susceptible Population



Your Sample



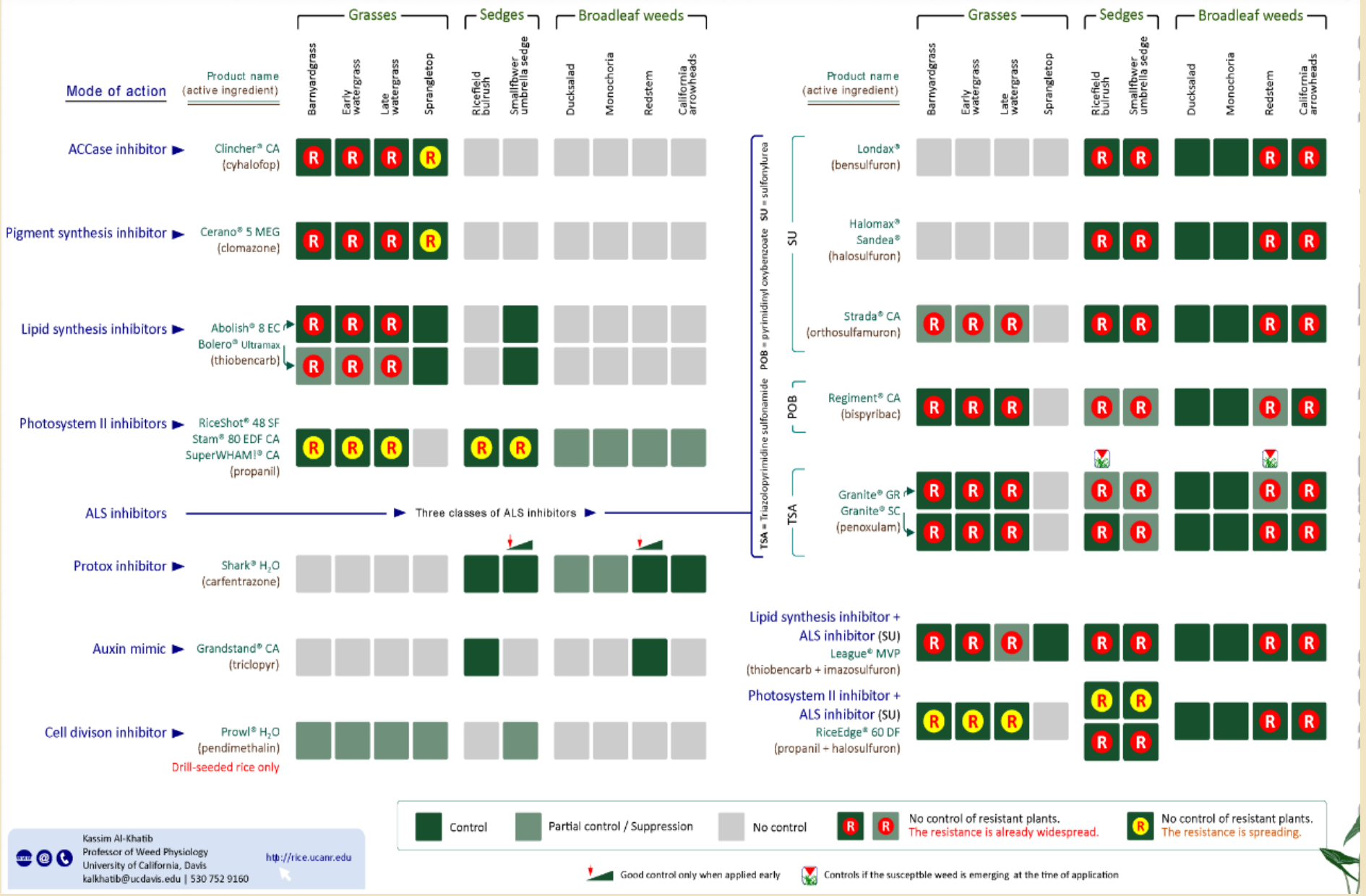
Summary Table: 2015 Resistance Testing

Weed species	# Samples	Abolish/ Bolero	Clincher	Cerano	Propanil	Regiment	Londax	Strada	Granite	Shark	Grandstand
Bulrush	4	-	-	-	1	-	-	2	0	0	0
Smallflower	30	0	-	-	24	-	30	30	-	0	-
E. Watergrass	2	2	1	1	1*	2	-	-	2*	-	-
L. Watergrass	6	6	6	4*	4*	6	-	-	5*	-	-
Barnyardgrass	10	7	6*	3*	4*	7	-	-	4*	-	-
Sprangletop	11	2	5	2	-	-	-	-	-	-	-

- Not tested with this herbicide/ In most cases, this herbicide is NOT labeled for this species.

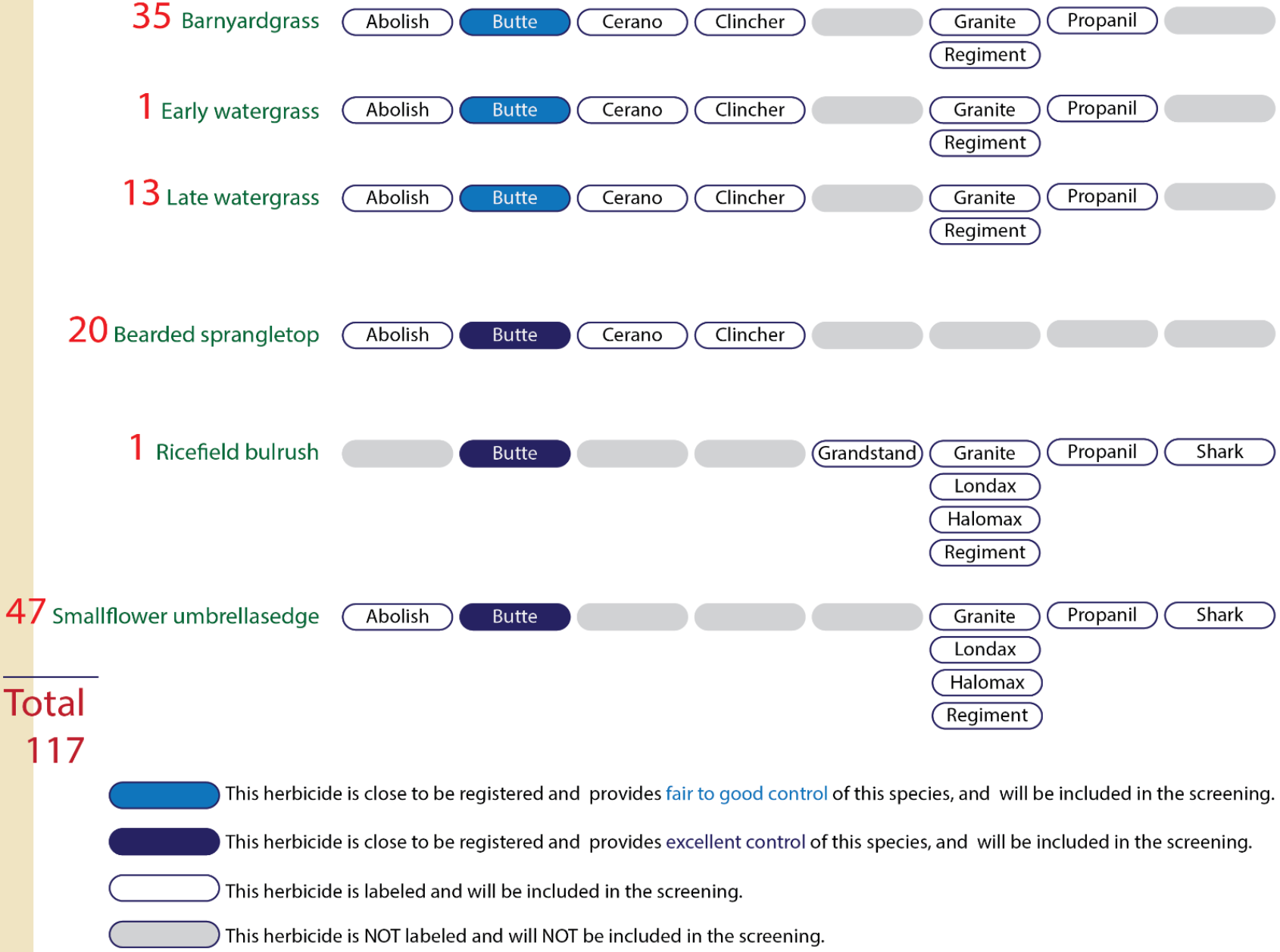
* Some samples tested had only a low level of resistance

2016 CALIFORNIA RICE WEED HERBICIDE SUSCEPTIBILITY CHART



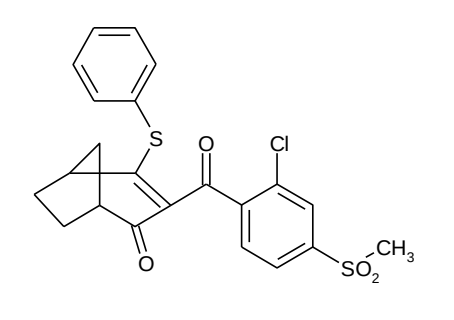
Kassim Al-Khatib
Professor of Weed Physiology
University of California, Davis
kalkhatib@ucdavis.edu | 530 752 9160
http://rice.ucanr.edu

2016 Number of samples and testing program



Benzobicyclon

- Benzobicyclon is a pro herbicide: Benzobicyclon hydrolysate (a metabolite) is a potent HPPD inhibitor.



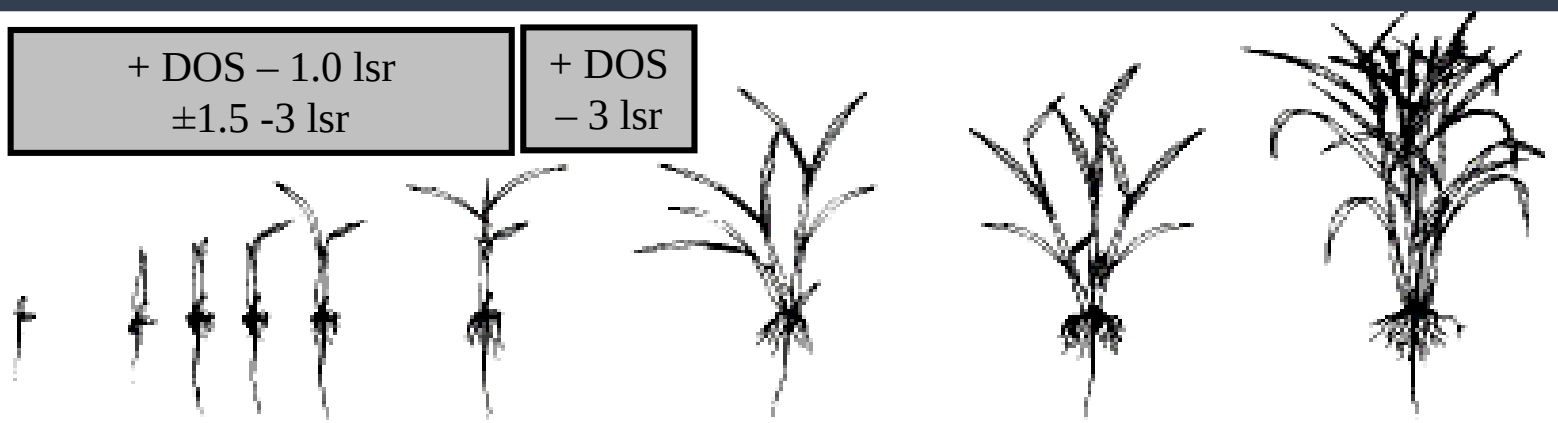
- Butte: benzobicyclon + halosulfuron
- Benzobicyclon (101 g ai/A) + Halosulfuron (21 g ai/A)
- Lactose based, light weight, granular herbicide formulation
  - Developed specifically for California
- Field Use Rates: 7.5 – 9.0 lbs./A
- Inhibition of 4-HPPD; HRAC: F2, WSSA Group: 27

+ control
-- no control
± suppression

	Barnyardgrass	E. watergrass	L. watergrass	Sprangletop	SF umbrella	RF Bulrush	CA arrowhead	Ducksalad	Redstem	Monochoria
Benzo + Halo	+ / ±	+ / ±	+ / ±	+	+	+	±	+ / ±	--	+

+ DOS – 1.0 lsr
±1.5 -3 lsr

+ DOS
– 3 lsr



preflood germination tiller initiation tillering panicle initiation flowering

***Watergrass*:**
½ leaf – 2 leaf

***Sprangletop*:**
PRE – 2.5 leaf

***Sedges.*:**
PRE – 5 leaf

Water Management

4” at time of application; 5-7 days static

Butte efficacy at 60 DAS

% control

Treatment	Rate	Timing	WG	ST	RBR	SF	DS
Butte	7.5 Ib	DOS	79	100	100	100	100
Butte	9 Ib	DOS	91	100	100	100	100
Butte	7.5 Ib	1 lst	89	100	100	100	100
Butte	9 Ib	1 lst	90	100	100	100	100
Butte + propanil + Grandstand	7.5 Ib + 6 qt + 8 oz	1 lst + 1 tiller + 1 tiller	96	100	100	100	100
Butte + Regiment	7.15 Ib + 0.67 oz	1 lst + 1 tiller	98	100	100	100	100
Butte + Clincher	7.5 Ib + 13 oz	1 lst + 1 tiller	93	100	100	100	100
Butte + Granite	7.5 Ib + 2.8 oz	1 lst + 1 tiller	97	100	100	100	100
Cerano + Butte	12 Ib + 7.5 Ib	DOS + 1 tiller	96	100	100	100	100
LSD (0.05)			7	ns	ns	ns	ns

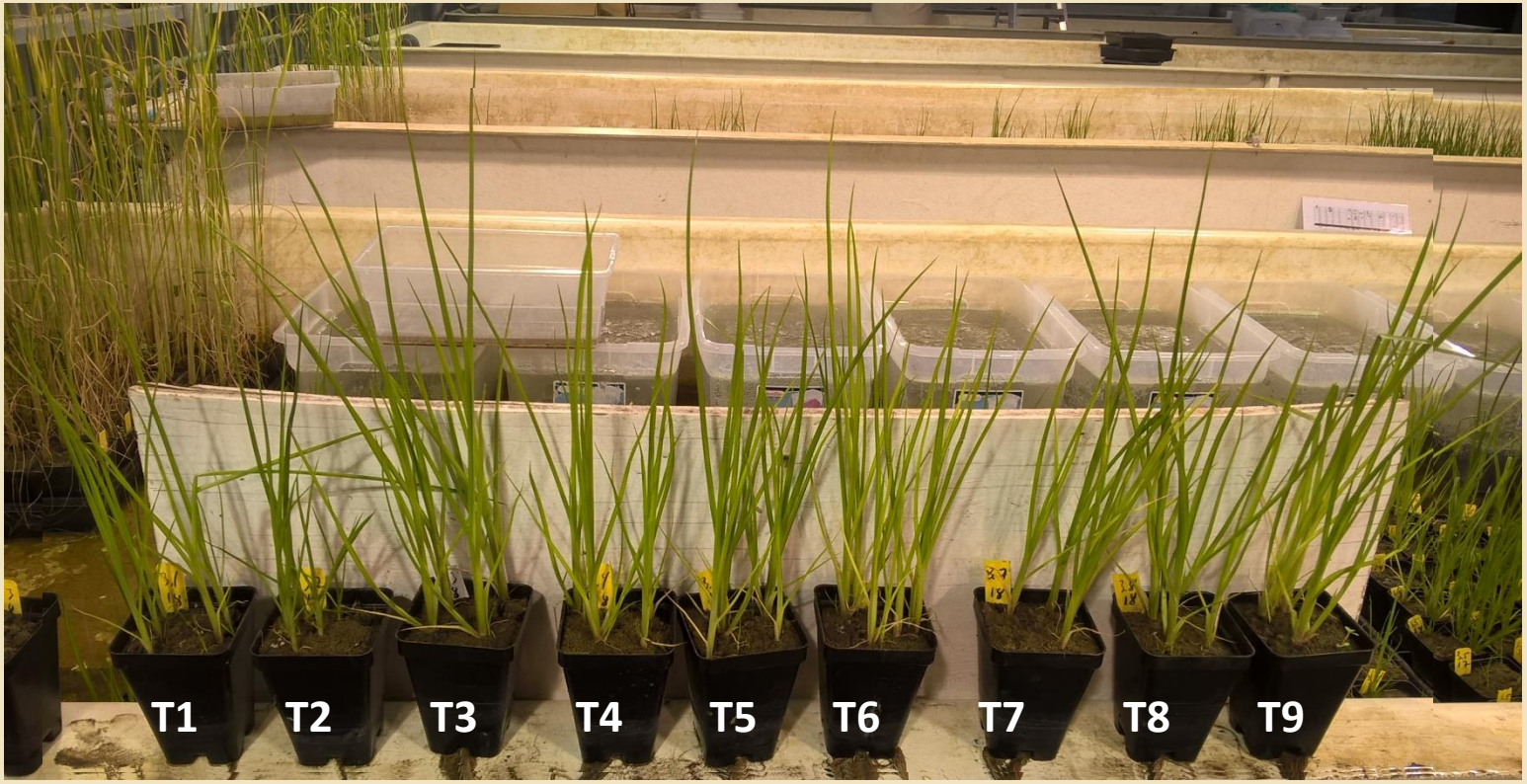
Rice yield as affected by Butte and Granite applications

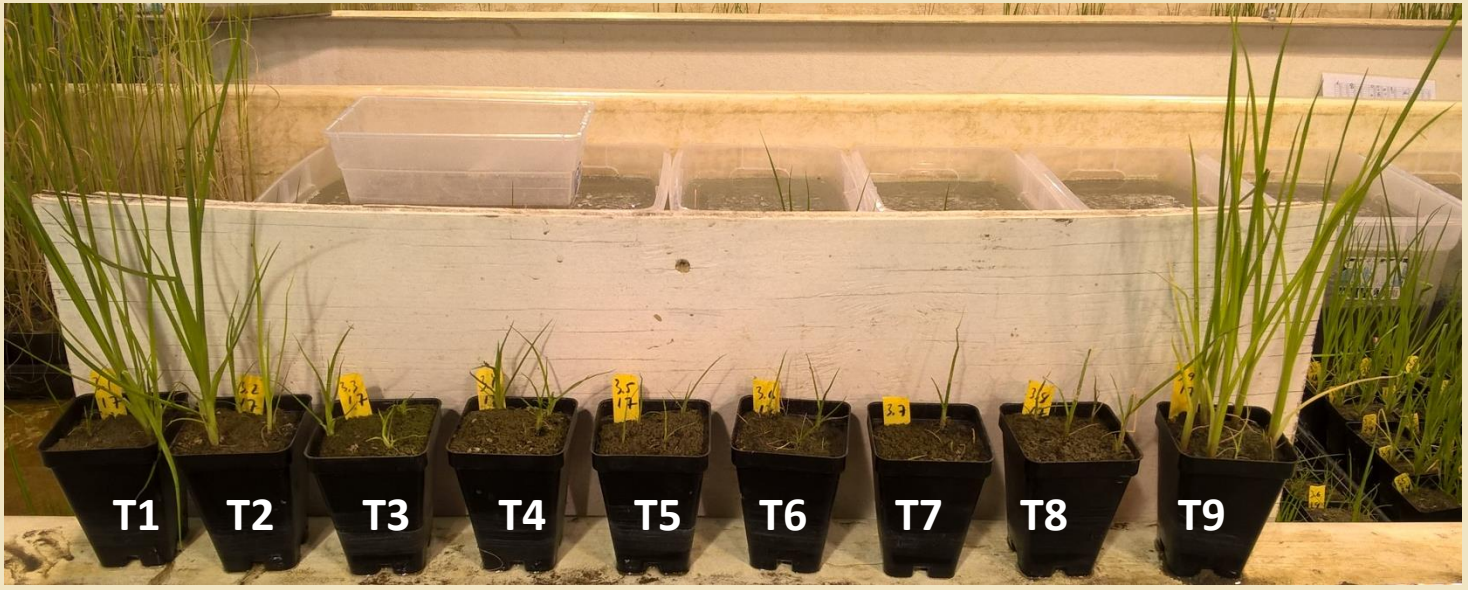
Treatment	Rate (per acre)	Timing	Stunting (%)	Yield (Ib/A)
Butte	7.5 Ib	1 lst	4	8.472
Butte + Granite	7.5 Ib + 2.0 oz	1 + 3 lst	10	8,529
Butte + Granite	7.5 Ib + 2.4 oz	1 + 3 lst	10	8,639
Butte + Granite	7.5 Ib + 2.8 oz	1 + 3 lst	13	8,295
Butte + Granite	7.5 Ib + 2.0 oz	1 + 5 lst	4	9,397
Butte + Granite	7.5 Ib + 2.4 oz	1 + 5 lst	5	9,580
Butte + Granite	7.5 Ib + 2.8 oz	1 + 5 lst	9	8,711
Butte + Granite	7.5 Ib + 2.0 oz	1 + 1 tiller	5	8,623
Butte + Granite	7.5 Ib + 2.4 oz	1 + 1 tiller	4	8,851
Butte + Granite	7.5 Ib + 2.8 oz	1 + 1 tiller	5	8,687
LSD (0.05)			10	1,454

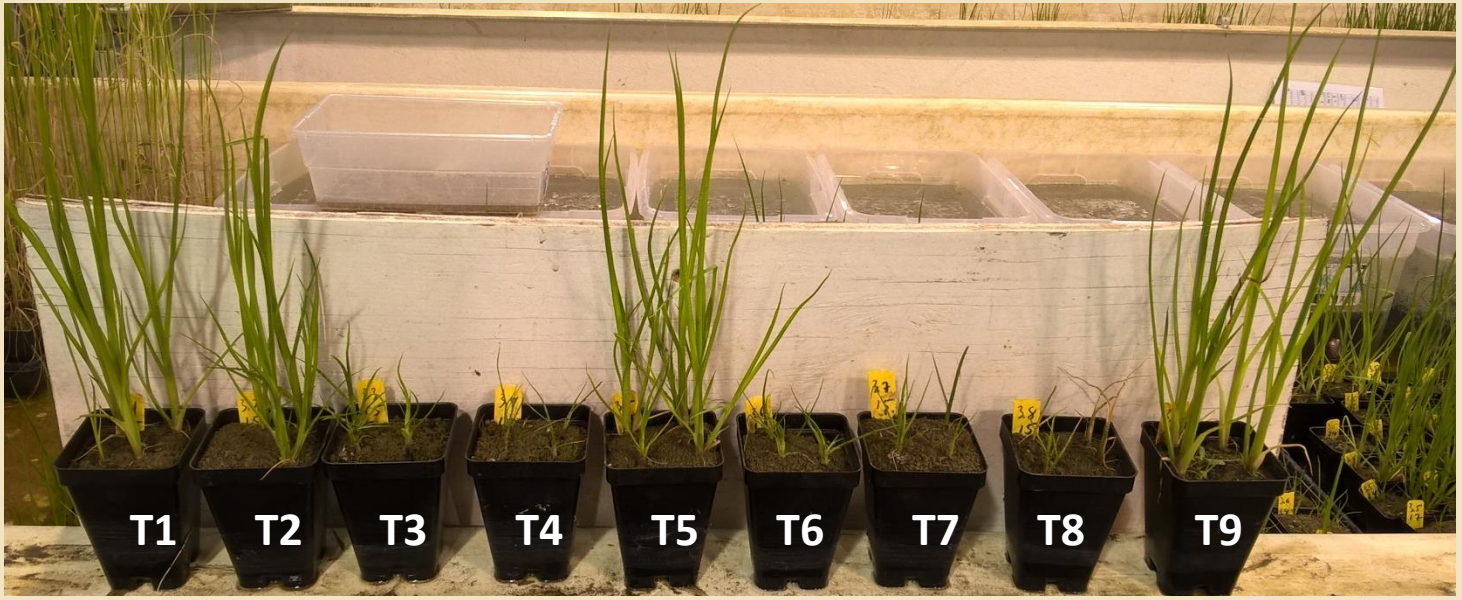
Mechanism of Herbicide Resistance

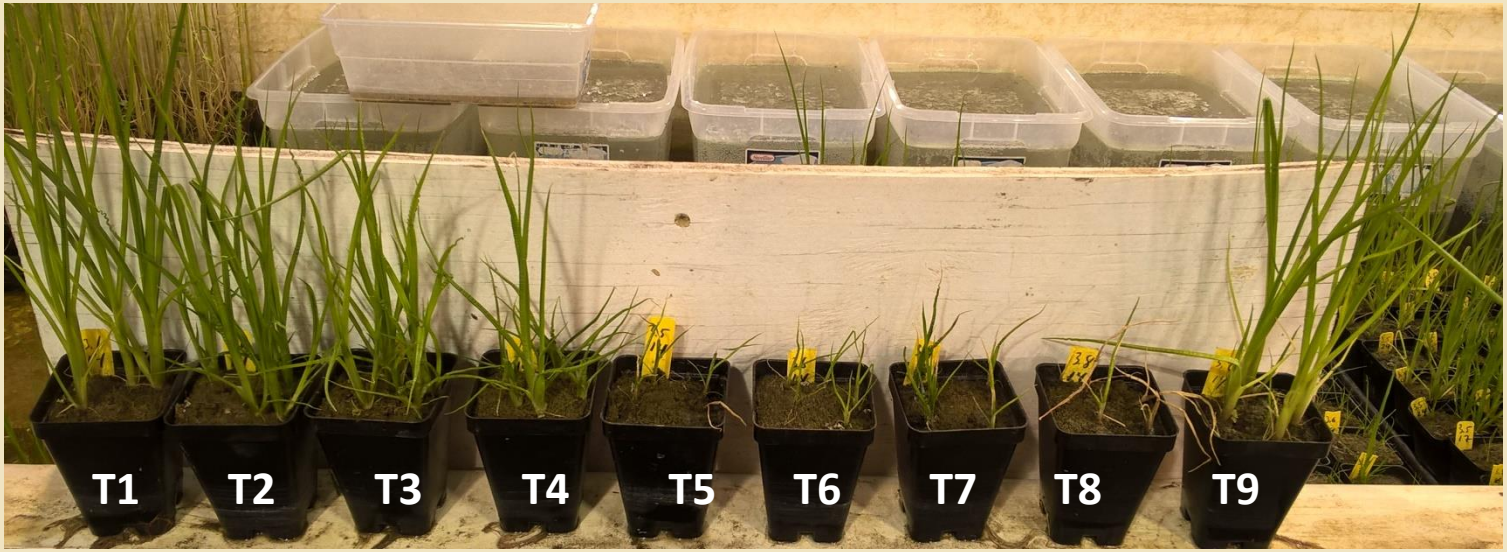
- Target site alteration
- Non-target-site-based mechanism
  - Metabolic
  - Translocation
  - Sequestration

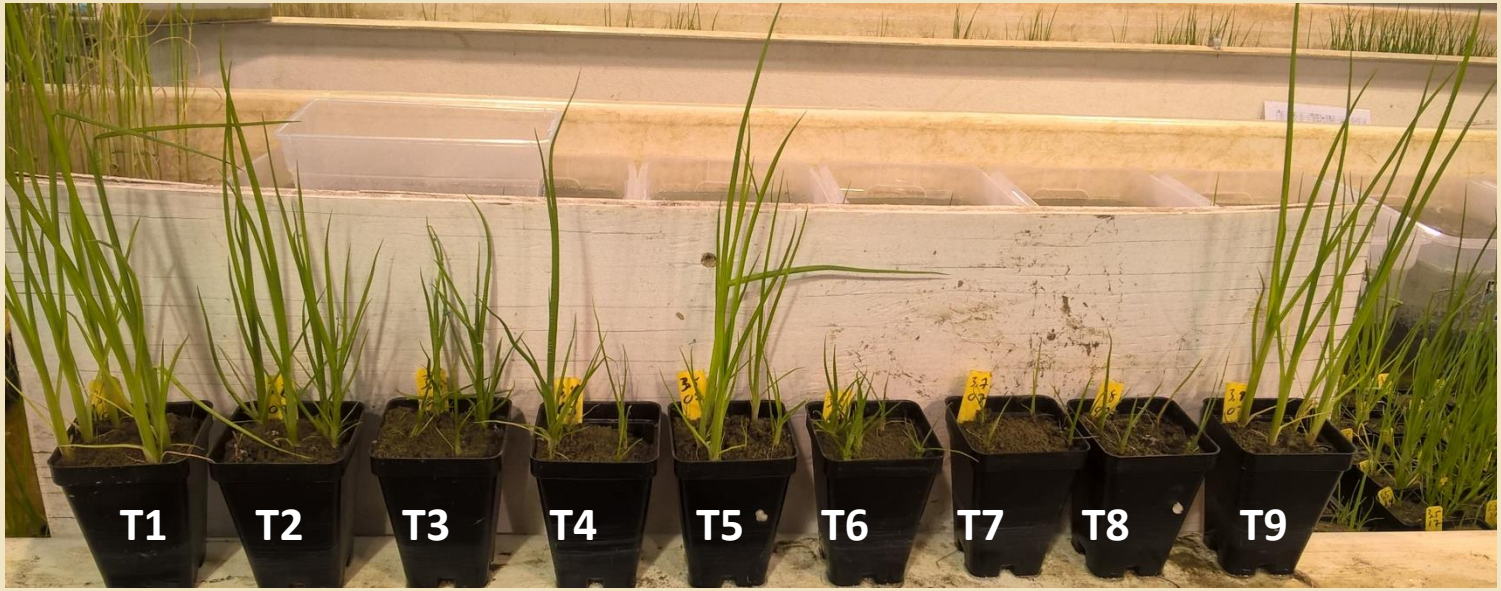

SUSCEPTIBLE
T1
T2
T3
T4
T5
T6
T7
T8
T9

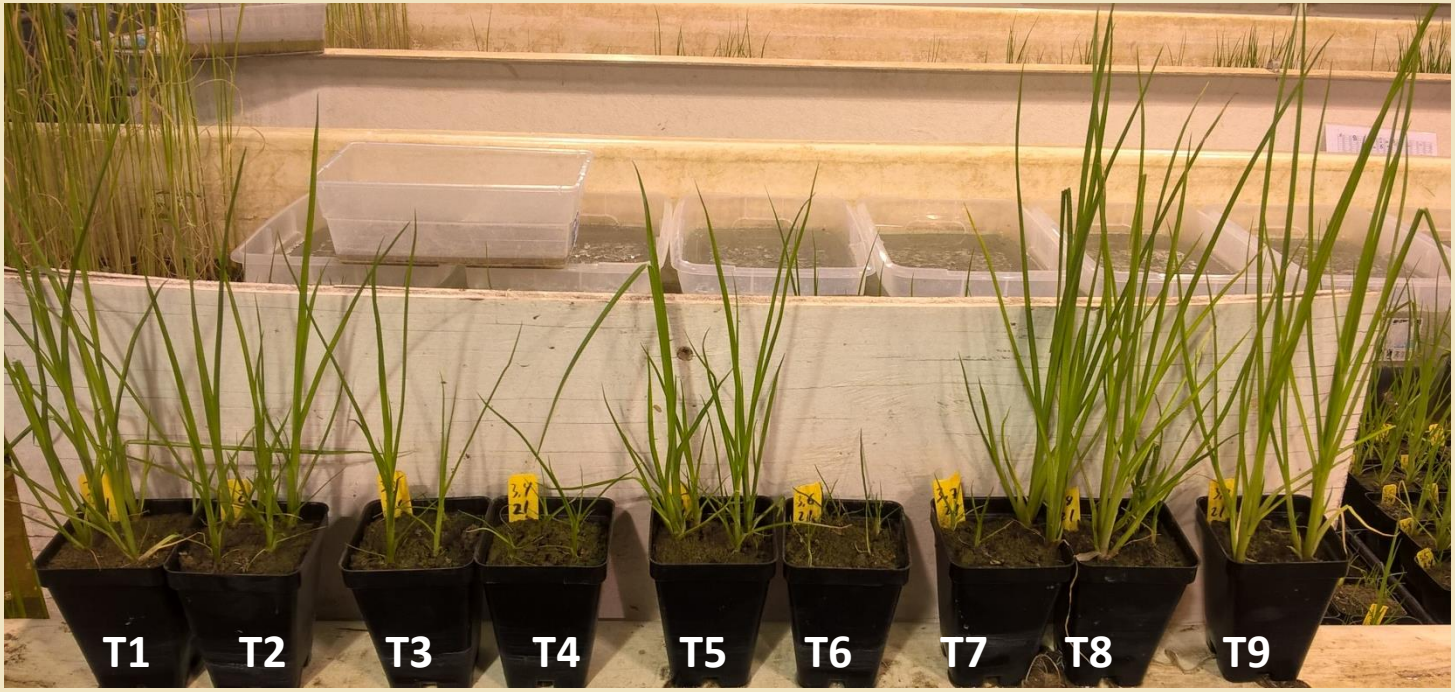

T1
T2
T3
T4
T5
T6
T7
T8
T9


T1
T2
T3
T4
T5
T6
T7
T8
T9


T1
T2
T3
T4
T5
T6
T7
T8
T9


T1
T2
T3
T4
T5
T6
T7
T8
T9

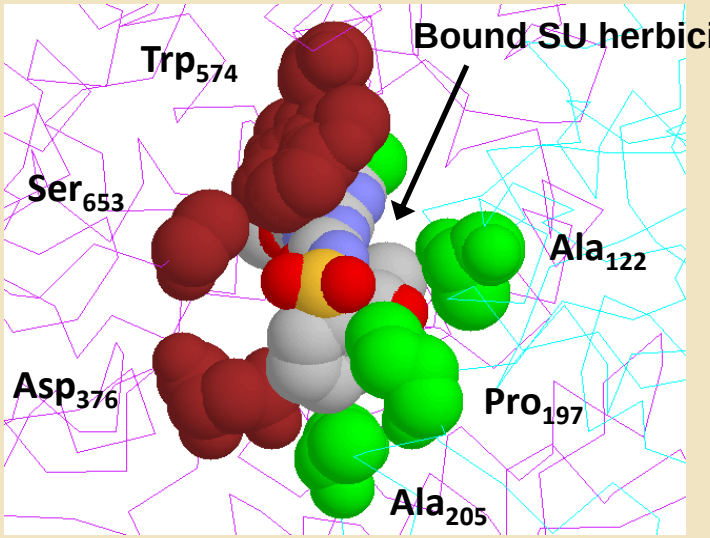

T1
T2
T3
T4
T5
T6
T7
T8
T9


T1
T2
T3
T4
T5
T6
T7
T8
T9

ALS-resistance

Cross-Resistance of ALS Mutations

Residue	Chemical Family		
	SUs	PTBs	TPs
Pro_{197}	HR	HR	HR
Ala_{205}	LR	LR	LR
Asp_{376}	HR	HR	HR
Arg_{377}	HR	nd	HR
Trp_{574}	HR	HR	HR
Ser_{653}	S	HR	S
Gly_{654}	LR	S	S

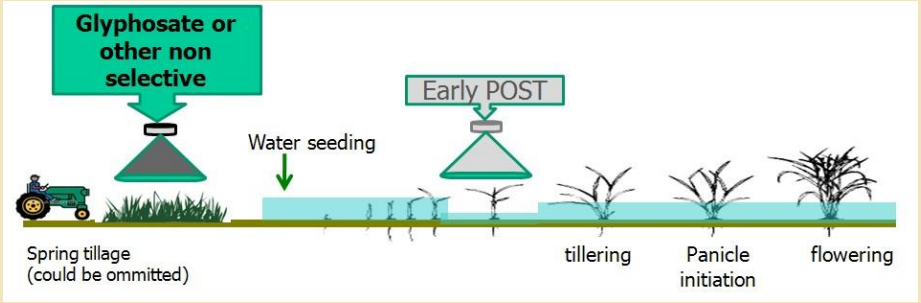


S = Susceptible
LR = Low resistance level (<10-fold)
HR = High resistance level (≥10-fold)
nd = no data available

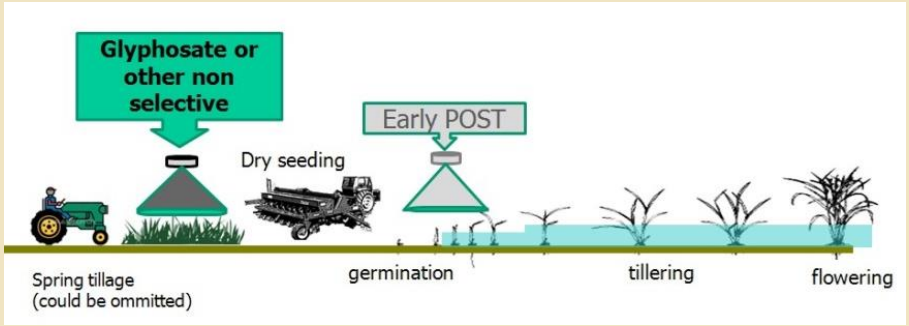
SU = Sulfonylurea
PTB = Pyrimidinylthiobenzoate
TP = Triazolopyrimidine

Systems to Consider

- Pre-planting weed control
  - Stale seeded
  - Minimum tillage

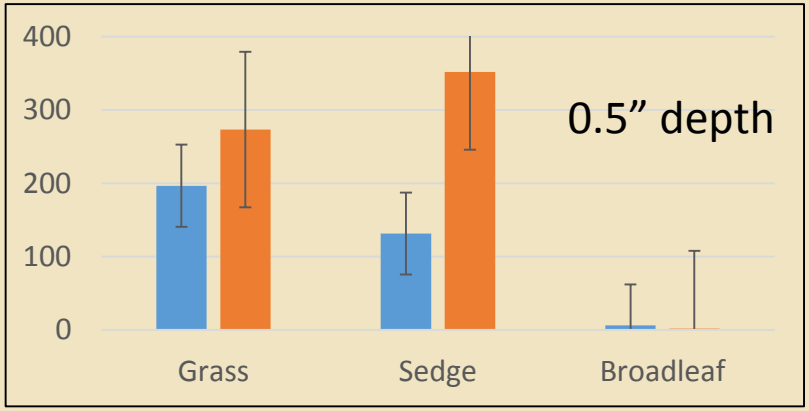


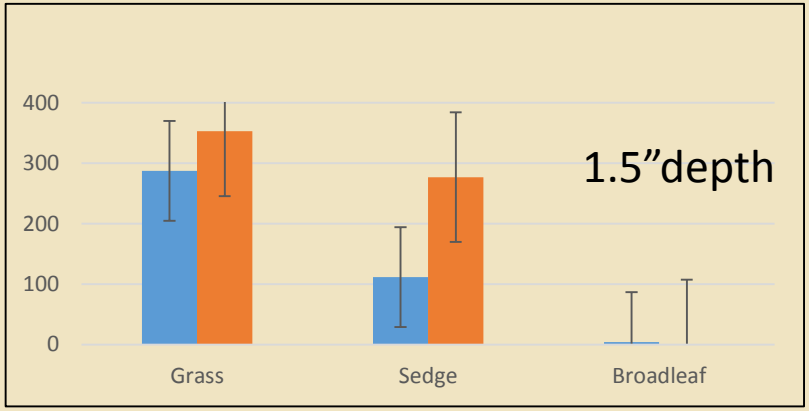
- Dry seeding
  - Drill
  - Broadcast



Weed control in direct seeded rice planted at different depth

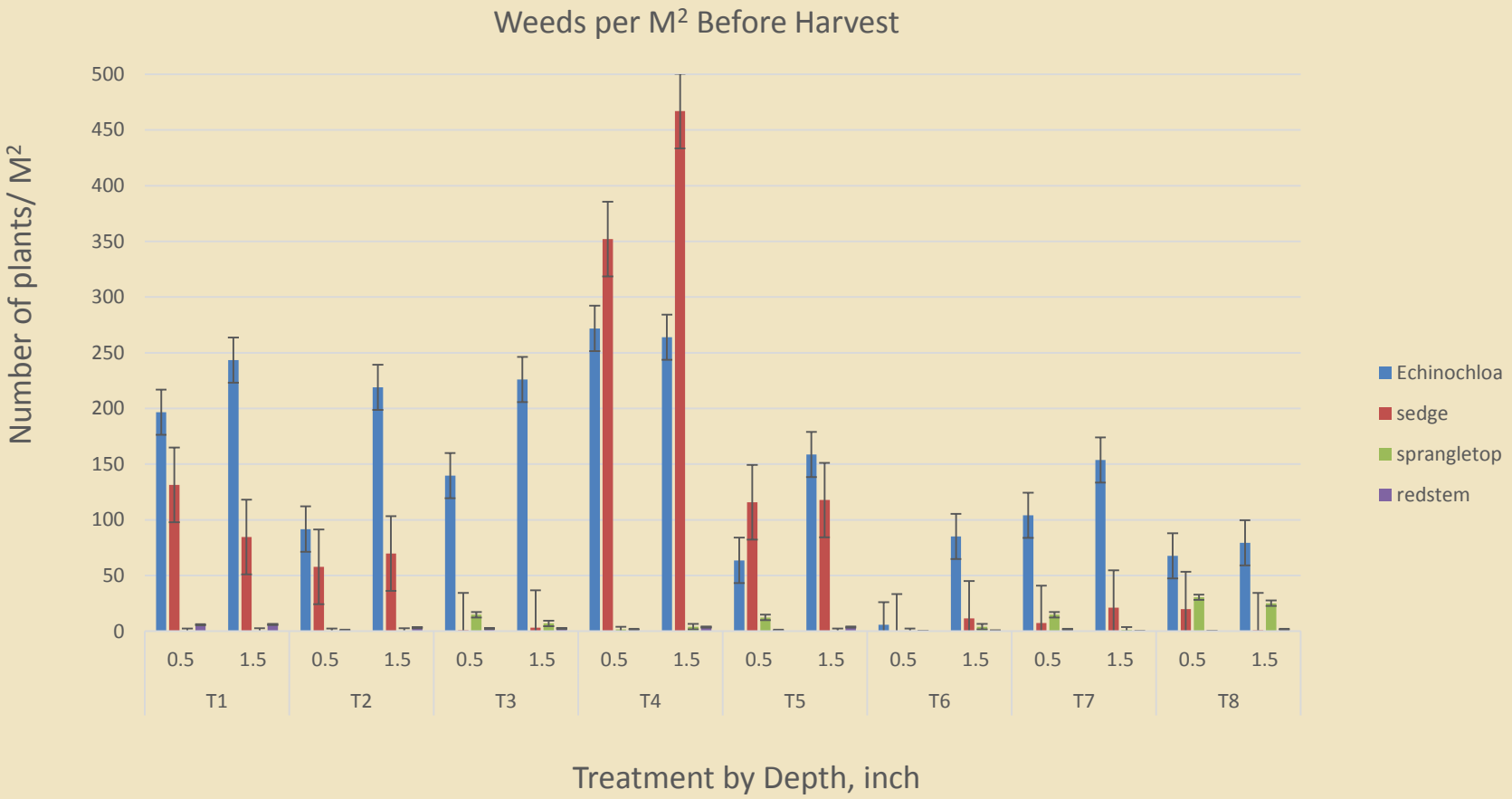
Number of Grass , Sedges, and Broadleaf Weeds per M^2, 130 DAP





Glyphosate

Weedy control



Treatment 1: Glyphosate only
T2: Glyphosate + Prowl H2O
T3: Glyphosate + Prowl H2O + Halomax
T4: untreated control
T5: Glyphosate + Prowl H2O + Clincher
T6: Glyphosate + Prowl H2O + Clincher, Granite SC
T7: Glyphosate + Prowl H2O + SuperWham (@3-4 LS*)
T8: Glyphosate + Prowl H2O + SuperWham (@4-5 LS*)

Weed control in direct seeded rice planted at different depth

Planting depth (inches)	Number of rice tiller (tiller per meter)		
	Nontreated control	Glyphosate	Glyphosate + pendimethalin fb cyhalofop
0.5	56	94	141
1.5	40	76	123

ACKNOWLEDGMENT

- Rice Research Board for funding
- Kent McKenzie, Director of Rice Research Station-Biggs
- Amar Godar, SRA III
- Whitney Brim-DeForest, Rice Advisor
- Alex Ceseski, Ph.D. student
- Kate McCauley, PhD student
- Mariano Galla, Ph.D. student