Herbicidal Efficacy Testing, Crop Safety Evaluations, and Glyphosate-Resistant Weed Management

Project No.: **14-HORT12-Hanson**

Project Leader: Brad Hanson
University of California, Davis
Plant Science Dept. MS-4
One Shields Ave
Davis, CA 95616
530.752.8115
bhanson@ucdavis.edu

Project Cooperators and Personnel:
David Doll, UCCE - Merced County
Franz Niederholzer, UCCE – Colusa, Sutter/Yuba Counties
John Roncoroni, UCCE - Napa County
Seth Watkins, Staff Research Associate, UC Davis
Lynn Sosnoskie, Project Scientist, UC Davis
Bahar Yildiz Kutman, Postdoctoral Researcher, UC Davis
Marcelo Moretti, Caio Brunharo, and Mariano Galla, PhD Student, UC Davis

Objectives:

The overall goals of the tree and vine weed science research and extension program at UC Davis (http://ucanr.org/brad.hanson) is to provide information on weed management and herbicide issues to California growers, pest control advisors, and the UC Cooperative Extension network. Although the almond industry is one of the key stakeholder groups for this program, the majority of our research is broadly applicable to, and partially supported by, other orchard and vineyard commodities in the state and the pest control industry.

As in previous years, the objectives proposed for the 2014-15 Almond Board of California fiscal year mirror the major research areas in our program:

1. Evaluation and testing of newly registered materials, tank mix partners, and application techniques for control of weeds with a special focus on glyphosate-resistant species.
2. Evaluating herbicide injury symptoms in almonds and developing training tools for Farm Advisors and pest control industry advisors and consultants.

Interpretive Summary:

Weed management issues such as new weeds, herbicide resistance, crop injury, and changing pesticide regulations significantly impact orchard cropping systems. Rapid and accurate responses depend on having an experienced research team with direct knowledge of weed control tactics used in each crop. The broad weed management research partially supported by this Almond Board of California project provides direct and practical benefits to almond producers, pest control advisors, county-based cooperative extension advisors, as well as related orchard and nursery industries.

Our statewide research and extension program is designed to balance the solutions-based research needs of orchardists and the crop protection industry with the need to develop an understanding of biological principles that impact weeds and weed control in these cropping systems. Results are routinely disseminated through conventional outreach venues such as the annual Almond Industry Conference and the UC Cooperative Extension network as well as online resources like the Weed Research and Information Center (www.wric.ucdavs.edu), the UC Weed Science blog (http://ucanr.edu/blogs/UCDWeedScience/index.cfm), and the Almond Doctor blog (http://thealmonddoctor.com/).

Materials and Methods:

Herbicide efficacy: We conducted over 15 herbicide efficacy trials in commercial orchards or at research stations in FY2014, primarily in almonds but some protocols were also tested in other orchard and vineyard crops. In order to address differences in weeds, soil conditions, and production practices, orchard trials ranged from Glenn to Kern County during this reporting period.

Herbicides in the small-plot experiments usually were applied using CO2 pressurized backpack sprayers while treatments in large-plot experiments were treated with an ATV mounted research sprayer. In the small plot trials, plots typically were 7 ft wide (strips) by 20-40 ft long and replicated four times. In the large plot trials, plots were 7 ft wide and 100-250 ft long and replicated three times. In most field trials, visual weed control evaluations were made at approximately monthly intervals during the season. In a few specific trials, quantitative weed count and biomass data also were collected. Herbicide efficacy treatments focused on residual herbicide comparisons and on POST control of key weeds including glyphosate-resistant hairy fleabane and junglerice. Control of other common orchard weeds including yellow nutsedge, mallow, and cut-leaf geranium was evaluated if present.

Greenhouse experiments and weed screening tests were conducted to support the field work, answer grower questions, and to develop extension materials. Species of most interest this year included Palmer amaranth, annual bluegrass, witchgrass, goosegrass, and ryegrass. A number of herbicide panel screens and level of resistance studies were conducted and wild radish were subjected to dose-response testing in the greenhouse to evaluate the level of tolerance/resistance to glyphosate or other herbicides (**Figure 2**).

Because almonds and other tree nuts are harvested from the orchard floor, late season weed control is very important; however, complete control of mature weeds can be difficult to achieve. In some cases, survivors regrow and still set seed and contribute to the soil seed bank. This partial control may be a contributing factor to herbicide resistance in some species. Greenhouse and field experiments continue in order to evaluate the effects of weed size on the reproductive ability of glyphosate-resistant weeds in Central Valley perennial cropping systems.

Crop safety experiments: Several research and demonstration experiments were initiated or are continuing to address herbicide injury questions from the almond industry and UCCE Farm Advisors. We expect that these types of projects will continue and evolve as needed to address real or perceived evolving issues with herbicide safety in tree crops. Photos from previous demonstrations have been used during Farm Advisor training sessions. Many of these photos were uploaded into an online symptomology website developed by Dr. Kassim Al-Khatib and launched in Jan. 2015 (http://herbicidesymptoms.ipm.ucanr.edu/index.cfm). The symptoms from additional herbicides, through both soil and foliar exposure, are underway on potted almond trees.

Related research: Although not directly supported by the Almond Board of California, two related lines of research applicable to almond production continue. With support of the CDFA-Specialty Crop Block Grant Program, we are determining the underlying genetics and physiological causes of glyphosate resistance in junglerice and other related grasses are being explored by a recently hired postdoctoral researcher. This project, which is based on earlier Almond Board of California funded research, will directly contribute to almond weed control recommendations and will also provide long-term support toward the understanding of resistance in California perennial crops. In a second project, a postdoctoral researcher working in collaboration with the weed program and Dr. Patrick Brown is conducting research on the interactions among glyphosate and almond micronutrient status. Both of these research areas were initiated in direct response to grower and almond industry questions.

Results and Discussion:

Because of the number of almond-related projects conducted and the diverse funding that supported this research, only a portion of the FY2014 weed science research is presented and discussed. The selected data that follows present some of the most relevant results and reflect the breadth of our program partially supported by the Almond Board of California.

Label changes: Few major herbicide registration changes were made in FY2014 that affect almond (**Figure 1**). The most important change affecting almond producers is that the Alion label now has a soil organic matter rate limitation (3.5 fl oz rate in most Central Valley soils) and the herbicide cannot be used in flood-irrigated orchards. As noted last year, Rely 280 is off patent and several additional generic glufosinate products entered the market this year. Registration of a new mode of action herbicide for almonds and other tree crops is expected by the end of 2015; Broadworks herbicide from Syngenta should be available in time for use this winter. This herbicide has the active ingredient mesotrione and is a bleaching herbicide that will primarily be used for preemergence control of broadleaf weeds.

Residual herbicides: As in the past few years, drought conditions challenged our residual herbicide research just like the commercial orchards. However, several experiments were conducted to compare the efficacy of PRE herbicides alone or in combination with a particular focus on tankmix combinations including Alion, Broadworks, PindarGT, and Matrix (**Tables 1-3**).

We repeated a large plot demonstration trial near Escalon this year. This site was a young orchard with a heavy and diverse weed population but was dominated by hairy fleabane and threespike goosegrass. These plots were treated in 2013/13 and 2014/15 with the same residual herbicide treatments (**Table 1**). In 2013, the burndown partner was glyphosate but in 2014 we included both Rely 280 and Roundup Powermax to ensure effective control of existing weeds. That study demonstrated the value of good burndown and the benefits of a multi-year approach to managing tough weed situations.

Several trials were conducted to evaluate Broadworks (mesotrione) as part of an orchard herbicide program (**Table 2**). At a site near Arbuckle, the combination treatments controlled broadleaf weeds well, but validated the previous observation that Broadworks does not provide any appreciable grass control. It is complementary to many herbicides used in almonds and will provide an additional mode of action to help manage glyphosate-resistant broadleaf weeds.

Because of the Alion label changes, trials were conducted to evaluate the duration of weed control with lower rates of this herbicide alone or in combination with other preemergence products (**Table 3**). As expected, the lower rates of Alion should not be expected to maintain weed control efficacy for as long as the previous maximum label rates. However, with effective tankmix partners or sequential treatments, excellent weed control and better resistance management is obtainable.

A series of experiments were conducted in almond and other tree crops to evaluate an experimental residual herbicide coded 1171 (**Tables 4-7**). In almond trials near Arbuckle and Davis, the product appeared safe on almond and relatively effective on several common orchard weeds. This product is in the early stages of evaluation so the manufacturer will be deciding whether to they want to pursue registration in almond.

<u>Postemergence herbicides</u>: A few trials were conducted in late 2014 and in 2015 to evaluate POST weed control. A postemergence treatment comparison was conducted in April in an almond orchard near Wasco dominated by glyphosate-resistant junglerice (**Table 8**). This experiment was repeated in 2015 (data under analysis) but, thus far, glyphosate-resistant junglerice does not seem to have any unexpected resistance to other herbicide modes of action.

Our work on the control and mechanisms of resistance to glyphosate and paraquat in hairy fleabane and horseweed continues. In the alternate control research conducted in the greenhouse and in commercial almond orchards, glyphosate- and paraquat- resistant hairy fleabane can still be adequately controlled with saflufenacil (Treevix) and glufosinate (Rely 280) as long as the plants are at a reasonable growth stage (**Figure 2**). Reduced translocation appears to be at least partially responsible for glyphosate resistance in both hairy fleabane and horseweed, although the mechanisms of this have not yet been elucidated (**Figure 3**).

Experiments initiated two years ago to evaluate the effects of hairy fleabane growth stage on survival, regrowth, and reproductive capacity continued this year (**Figure 4**). This was field validated in commercial almond orchards near Arbuckle (data under analysis).

Related research: In other projects related to our Almond Board funded research, we are conducting research on the biology and genetics of glyphosate-resistant junglerice (**Figures 6-9**) and conducting pilot research on other summer annual grasses known or suspected to also be resistant to glyphosate.

In cooperation with Patrick Brown, and with funding from the fertilizer industry, we are exploring the interactions among glyphosate and micronutrients in the soil and in plant foliage following simulated glyphosate drift (**Figures 10-11**). This ongoing work, which includes almonds as well as several annual crops, has resulted in very interesting observations on crop injury, nutrient toxicity, and remediation strategies.

Finally, we continue to develop our knowledge and the database on herbicide injury symptoms on almonds in support of Farm Advisor, PCA, and industry questions following incidents of drift or other non-target damage from herbicides (**Figure 12**).

Research Effort Recent Publications:

Hanson, B., S. Wright, L. Sosnoskie, A. Fisher, M. Jasieniuk, J. Roncoroni, K. Hembree, S. Orloff, A. Shrestha, and K. Al-Khatib. 2014. Herbicide resistant weeds challenge signature California cropping systems. California Agriculture 68:142-152

Gao, S., L. Sosnoskie, A. Cabrera, R. Qin, B. Hanson, J. Gerik, D. Wang, G. Browne, J. Thomas. 2015. Fumigation efficacy and emission reduction using low permeability films. Pest Manage. Sci. Online: DOI 10.1002/ps.3993

Cabrera, J.A., B.D. Hanson, R. Qin, J.S. Gerik, D. Wang, G.T. Browne, and S. Gao. 2015. Efficacy of 1,3-dichloropropene plus chloropicrin reduced rates under two different tarps against nematodes, pathogens and weeds. Crop Protection 75:34-39.

Nguyen, T.T., D.C. Slaughter, B.D. Hanson, A. Barber, A. Freitas, D. Robles, and E. Whelan. 2015. Automated mobile system for accurate outdoor tree crop enumeration using an uncalibrated camera. Sensors 15:18427-18422.

Moretti, M., A. Shrestha, K.J. Hembree, and B.D. Hanson. Postemergence control of glyphosate-paraquat resistant hairy fleabane (*Conyza bonariensis*) in tree nut orchards in the Central Valley of California. Weed Technol. (in press).

Hanson, B.D. and T.W. Miller. The importance of 2,4-D in orchard, vineyard, and berry crops in the United States. Book Chapter in Phenoxy Herbicide task force report. (in press).

Herbicide Registration on California Tree and Vine Crops -*(updated February 2015 - UC Weed Science)*

	Herbicide-Common Name *(example trade name)*	Site of Action Group[1]	Almond	Pecan	Pistachio	Walnut	Apple	Pear	Apricot	Cherry	Nectarine	Peach	Plum / Prune	Avocado	Citrus	Date	Fig	Grape	Kiwi	Olive	Pomegranate
			----- tree nut -------				- pome -		---------stone fruit ---------												
Preemergence	dichlobenil *(Casoron)*	L / 20	N	N	N	N	R	R	N	R	N	N	N	N	N	N	N	R	N	N	N
	diuron *(Karmex, Diurex)*	C2 / 7	N	R	N	R	R	R	N	N	N	R	N	N	R	N	N	R	N	R	N
	EPTC *(Eptam)*	N / 8	R	N	N	R	N	N	N	N	N	N	N	N	R	N	N	N	N	N	N
	flazasulfuron *(Mission)*	B / 2	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	R	N	N	N
	flumioxazin *(Chateau)*	E / 14	R	R	R	R	R	R	R	R	R	R	R	NB	NB	N	NB	R	N	R	R
	indaziflam *(Alion)*	L / 29	R	R	R	R	R	R	R	R	R	R	R	N	R	N	N	R	N	R	N
	isoxaben *(Trellis)*	L / 21	R	R	R	R	NB	NB	NB	NB	NB	NB	NB	NB	NB	N	NB	R	NB	NB	NB
	napropamide *(Devrinol)*	K3 / 15	R	N	N	N	N	N	N	N	N	N	N	N	N	N	N	R	R	N	N
	norflurazon *(Solicam)*	F1 / 12	R	R	N	R	R	R	R	R	R	R	R	R	R	N	N	R	N	N	N
	oryzalin *(Surflan)*	K1 / 3	R	R	R	R	R	R	R	R	R	R	R	R	R	N	R	R	R	R	R
	oxyfluorfen *(Goal, GoalTender)*	E / 14	R	R	R	R	R	R	R	R	R	R	R	R	NB	R	R	R	R	R	R
	pendimethalin *(Prowl H2O)*	K1 / 3	R	R	R	R	R	R	R	R	R	R	R	N	R	N	N	R	N	R	R
	penoxsulam *(Pindar GT)*	B / 2	R	R	R	R	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
	pronamide *(Kerb)*	K1 / 3	N	N	N	N	R	R	R	R	R	R	R	N	N	N	N	R	N	N	N
	rimsulfuron *(Matrix)*	B / 2	R	R	R	R	R	R	R	R	R	R	R	N	R	N	N	R	N	N	N
	sulfentrazone *(Zeus)*	E / 14	N	N	R	R	N	N	N	N	N	N	N	N	R	N	N	R	N	N	N
	simazine *(Princep, Caliber 90)*	C1 / 5	R	R	N	R	R	R	N	R[2]	R	R	N	R	R	N	N	R	N	R	N
Postemergence	carfentrazone *(Shark)*	E / 14	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
	clethodim *(SelectMax)*	A / 1	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	N	R	N	N	NB	N	NB	N
	clove oil *(Matratec)*	NC[3]	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
	2,4-D *(Clean-crop, Orchard Master)*	O / 4	R	R	R	R	R	R	R	R	R	R	R	N	N	N	N	R	N	N	N
	diquat *(Diquat)*	D / 22	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB	NB
	d-limonene *(GreenMatch)*	NC[3]	R	R	R	R	R	R	R	R	R	R	R	N	R	N	R	R	R	N	N
	fluazifop-p-butyl *(Fusilade)*	A / 1	NB	R	NB	NB	NB	NB	R	R	R	R	R	NB	R	NB	NB	R	N	NB	NB
	glyphosate *(Roundup)*	G / 9	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
	glufosinate *(Rely 280)*	H / 10	R	R	R	R	R	N	N	N	N	N	N	N	N	N	N	R	N	N	N
	halosulfuron *(Sandea)*	B / 2	N	R	R	R	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
	paraquat *(Gramoxone)*	D / 22	R	R	R	R	R	R	R	R	R	R	R	R	R	N	R	R	R	R	R
	pelargonic acid *(Scythe)*	NC[3]	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	N
	pyraflufen *(Venue)*	E / 14	R	R	R	R	R	R	R	R	R	R	R	N	N	R	R	R	R	R	R
	saflufenacil *(Treevix)*	E / 14	R	N	R	R	R	R	N	N	N	N	N	N	R	N	N	N	N	N	N
	sethoxydim *(Poast)*	A / 1	R	R	R	R	R	R	R	R	R	R	NB	NB	R	NB	NB	R	N	NB	NB

Notes: R = Registered, N = Not registered, NB = nonbearing. This chart is intended as a general guide only. Always consult a current label before using any herbicide as labels change frequently and often contain special restrictions regarding use of a company's product.

[1] Herbicide site of action designations are according to the Herbicide Resistance Action Committee (letters) and the Weed Science Society of America (number) systems. NC = no accepted site of action classification; these contact herbicides are general membrane disruptors.

[2] Simazine is registered on only tart cherry in CA.

Weed susceptibility information and the most up to date version of this table can be found at the Weed Research and Information Center (http://wric.ucdavis.edu)

Figure 1. Most recent update of tree and vine herbicide registration table. (Hanson)

Table 1. Selected weed control evaluations from 2014-15 large plot demonstration conducted in an almond orchard near Escalon, CA; second year treatments. (Watkins and Hanson)

	Treatment	Rate			28 DAT-A: Annual bluegrass	28 DAT-A: Hairy fleabane	28 DAT-A: 3 spike goose grass	28 DAT-A: Malva	59 DAT-A: Hairy fleabane	59 DAT-A: Filaree	59 DAT-A: Shep-herds purse
					% control						
1	Untreated check				-	-	-		-	-	-
2	Roundup PowerMax	1	lb ae/a	A	100	95	90	93	100	100	100
	AMS	2	qt/100 gal	A							
	Roundup PowerMax	1	lb ae/a	B							
	AMS	10	lb/100 gal	B							
3	Roundup PowerMax	1	lb ae/a	A	100	100	90	100	73	100	100
	AMS	2	qt/100 gal	A							
	Goal 2XL	5	pt/a	A							
	Surflan	4	qt/a	A							
4	Roundup PowerMax	1	lb ae/a	A	100	100	90	98	93	100	98
	AMS	2	qt/100 gal	A							
	Pindar GT	3	pt/a	A							
5	Roundup PowerMax	1	lb ae/a	A	100	87	90	93	63	100	73
	AMS	2	qt/100 gal	A							
	Prowl H20	4	qt/a	A							
6	Roundup PowerMax	1	lb ae/a	A	99	95	90	97	77	100	100
	AMS	2	qt/100 gal	A							
	Chateau	10	oz/a	A							
7	Roundup PowerMax	1	lb ae/a	A	98	98	90	97	77	100	100
	AMS	2	qt/100 gal	A							
	Prowl H20	4	qt/a	A							
	Chateau	10	oz/a	A							
8	Roundup PowerMax	1	lb ae/a	A	100	93	90	96	83	100	100
	AMS	2	qt/100 gal	A							
	Prowl H20	4	qt/a	A							
	Matrix SG	4	oz/a	A							
9	Roundup PowerMax	1	lb ae/a	A	100	93	90	77	73	100	100
	AMS	2	qt/100 gal	A							
	Alion	6.5	oz/a	A							
10	Roundup PowerMax	1	lb ae/a	A	98.3	93	87	50	67	100	98
	AMS	2	qt/100 gal	A							
	Trellis	1.3	lb/a	A							
11	Roundup PowerMax	1	lb ae/a	A	100	87	83	83	100	100	100
	AMS	2	qt/100 gal	A							
	Prowl H20	3	qt/a	A							
	Roundup PowerMax	1	lb ae/a	B							
	AMS	2	qt/100 gal	B							
	Prowl H20	2	qt/a	B							
12	Roundup PowerMax	1	lb ae/a	A	99	90	87	100	100	100	100
	AMS	2	qt/100 gal	A							
	Pindar GT	3	pt/a	A							
	Roundup PowerMax	1	lb ae/a	B							
	AMS	2	qt/100 gal	B							
	Prowl H20	2	qt/a	B							
	LSD (0.05)				***6***	***13***	***7***	***18***	***14***	***0***	***8***

" A" timing was applied on January 21, 2015 and the "B" timing on March 5, 2015. The same treatments were applied to these plots in 2014/15.

Note: the large-plot trials did not include an untreated control and, thus, had only 11 treatments.

Table 2. Selected weed control evaluations from 2014-15 Broadworks and Alion tankmix trial near Arbuckle, CA (Brunharo and Hanson)

	Treatment	Rate		56 DAT-A Filaree	56 DAT-A Hairy fleabane	56 DAT-A Chick weed	56 DAT-A Rye grass	103 DAT-A Hairy fleabane	103 DAT-A Bind weed	103 DAT-A Rye grass
				% control						
1	Rely 280	2	qt/a	0	0	0	0	15	8	0
2	Alion	3.5	fl oz/a	93	88	96	88	81	99	98
	Rely 280	2	qt/a							
3	Alion	5	fl oz/a	99	99	99	40	83	47	98
	Rely 280	2	qt/a							
4	Matrix	4	oz/a	95	100	85	90	76	95	96
	Rely 280	2	qt/a							
5	Alion	3.5	fl oz/a	97	93	90	53	99	76	100
	Matrix	2	oz/a							
	Rely 280	2	qt/a							
6	Alion	3.5	fl oz/a	99	95	85	48	79	100	100
	Matrix	4	oz/a							
	Rely 280	2	qt/a							
7	Broadworks	6	fl oz/a	66	75	50	18	99	55	25
	Rely 280	2	qt/a							
8	Alion	3.5	fl oz/a	99	90	83	70	83	96	75
	Broadworks	6	fl oz/a							
	Rely 280	2	qt/a							
9	Alion	5	fl oz/a	98	98	97	96	92	87	100
	Broadworks	6	fl oz/a							
	Rely 280	2	qt/a							
10	Alion	5	fl oz/a	99	75	92	55	93	78	100
	Broadworks	3	fl oz/a							
	Rely 280	2	qt/a							
11	Broadworks	6	fl oz/a	72	95	95	30	99	98	53
	Prowl H2O	4	qt/a							
	Rely 280	2	qt/a							
12	Broadworks	6	fl oz/a	85	65	85	53	93	87	88
	Surflan	4	qt/a							
	Rely 280	2	qt/a							
13	Broadworks	6	fl oz/a	82	88	81	53	96	92	50
	GoalTender	3	pt/a							
	Rely 280	2	% v/v							
14	Broadworks	6	fl oz/a	87	93	74	55	96	92	74
	Matrix	2	oz/a							
	Rely 280	2	qt/a							
15	Broadworks	6	fl oz/a	94	100	91	64	99	78	95
	Matrix	4	oz/a							
	Rely 280	2	qt/a							
16	Pindar GT	2.5	pt/a	95	73	58	20	65	45	70
	Rely 280	2	qt/a							
	LSD (0.05)			***23***	***32***	***39***	***50***	***27***	***29***	***41***

* "A" timing was applied on January 16, 2014 and the "B" timing on March 18, 2014.
Note: the large-plot trials did not include an untreated control and, thus, had only 11 treatments.

Table 3. Selected weed control evaluations from 2014-15 comparison of Alion and other preemergence tankmix and sequential partners in an almond orchard near Escalon, CA. All treatments included a high rate of Rely 280 and Roundup Powermax to ensure good control of existing weeds. (Watkins and Hanson)

					Hairy fleabane	3 spike goose grass	Hairy fleabane	3 spike goose grass	Hairy fleabane	3 spike goose grass	Overall
					92 DAT		128 DAT		-------156 DAT --------		
	Treatment	Rate			------------------------------------ % control ------------------------------------						
1	Untreated Check				0	0	0	0	0	0	0
2	Alion	2.5	oz/a	A	55	75	58	80	53	83	58
3	Alion	3.5	oz/a	A	73	78	71	88	65	85	75
4	Alion	5	oz/a	A	85	93	84	93	85	90	91
5	Chateau	10	oz wt/a	A	78	65	73	73	68	70	68
6	Matrix	4	oz wt/a	A	98	63	99	55	95	20	58
7	Pindar GT	2.5	pt/a	A	85	60	80	55	70	60	48
8	Goaltender	4	pt/a	A	73	85	65	68	60	85	58
9	Alion Chateau	5 6	oz/a oz wt/a	A	97	98	93	93	90	90	93
10	Alion Matrix	5 2	oz/a oz wt/a	A	90	95	95	95	93	90	94
11	Alion Pindar GT	5 1.5	oz/a pt/a	A	100	96	99	91	100	93	95
12	Alion Goaltender	5 2	oz/a pt/a	A	93	98	90	96	90	98	94
13	Chateau Alion	10 3.5	oz wt/a oz/a	A B	92	98	90	100	85	98	92
14	Chateau Alion	12 5	oz wt/a oz/a	A B	97	99	96	100	94	96	96
15	Matrix Alion	4 5	oz wt/a oz/a	A B	100	100	97	99	100	100	99
16	Alion Alion	5 5	oz/a oz/a	A B	94	100	90	100	90	100	93
17	Alion	3.5	oz/a	B	85	98	65	95	43	95	75
18	Alion	5	oz/a	B	93	98	83	95	73	95	88
LSD (P=.05)					**10**	**13**	**11**	**14**	**16**	**12**	**10**

The “A” timing was applied on January 13, 2015 and the “B” timing on March 5, 2015. All treatments at both timings included Roundup Powermax plus Rely 280 and AMS for control of emerged weeds. The same treatments were applied to these plots in 2014/15.

Table 4. Control of hare barley with experimental herbicide SP1171 in an almond orchard trial near Arbuckle, CA in 2015 (Galla and Hanson).

Treatment	Rate		1 MAT		2 MAT		3 MAT	
			%					
Untreated Check			0	b	0	b	0	b[1]
SP1171	12.8	fl oz/a	97.5	a	92.5	a	97.5	a
SP1171	19.2	fl oz/a	97.5	a	97.5	a	97.5	a
SP1171	25.6	fl oz/a	100	a	100	a	100	a
SP1171	51.2	fl oz/a	96.3	a	97.5	a	93.8	a
Chateau	6	oz/a	97.5	a	92.5	a	96.3	a
Chateau	12	oz/a	98.8	a	93.8	a	93.8	a
Chateau + SP1171	6 +12.8	oz +fl oz/a	95	a	92.5	a	97.5	a
Chateau + SP1171	6 + 19.2	oz/a + fl oz/a	98.8	a	98.8	a	93.8	a

Treatments applied January 22, 2015. Means followed by same letter do not significantly differ (P=.05, Tukey's HSD)

Table 5. Control of redstem filaree with experimental herbicide SP1171 in an almond orchard trial near Arbuckle, CA in 2015 (Galla and Hanson).

Treatment	Rate		1 MAT		2 MAT		3 MAT	
			%					
Untreated Check			0	b	0	c	0	b[1]
SP1171	12.8	fl oz/a	93.8	a	100	a	90	a
SP1171	19.2	fl oz/a	97.5	a	100	a	98.1	a
SP1171	25.6	fl oz/a	100	a	100	a	99.4	a
SP1171	51.2	fl oz/a	98.8	a	97.5	b	99.7	a
Chateau	6	oz/a	98.8	a	100	a	100	a
Chateau	12	oz/a	100	a	100	a	100	a
Chateau + SP1171	6 +12.8	oz +fl oz/a	98.8	a	100	a	98.7	a
Chateau + SP1171	6 + 19.2	oz/a + fl oz/a	98.8	a	100	a	100	a

Treatments applied January 22, 2015. Means followed by same letter do not significantly differ (P=.05, Tukey's HSD)

Table 6. Control of hare barley with experimental herbicide SP1171 in an almond orchard trial near Davis, CA in 2015 (Galla and Hanson).

			1 MAT		2 MAT		3 MAT	
Treatment		Rate	----------------------		%		----------------------	
SP1171	12.8	fl oz/a	15.7	a	8.6	a	2.7	a[1]
SP1171	19.2	fl oz/a	0.8	b	1.5	a	0.7	a
SP1171	25.6	fl oz/a	2.5	b	1.8	a	5.6	a
SP1171	51.2	fl oz/a	0.3	b	0.8	a	0.5	a
Chateau	6	oz/a	0	b	1.3	a	1.1	a
Chateau	12	oz/a	1.2	b	2.9	a	3.6	a
Chateau + SP1171	6 +12.8	oz +fl oz/a	0	b	1.8	a	2.4	a
Chateau + SP1171	6 + 19.2	oz/a + fl oz/a	1.6	b	3.2	a	1.4	a

Treatments applied January 20, 2015. Means followed by same letter do not significantly differ (P=.05, Tukey's HSD).

Table 7. Control of field bindweed with experimental herbicide SP1171 in an almond orchard trial near Davis, CA in 2015 (Galla and Hanson).

			1 MAT		2 MAT		3 MAT	
Treatment		Rate	----------------------		%		----------------------	
SP1171	12.8	fl oz/a	2	a	0.4	a	0.5	a[1]
SP1171	19.2	fl oz/a	2	a	0.7	a	2.8	a
SP1171	25.6	fl oz/a	2.5	a	0.3	a	0	a
SP1171	51.2	fl oz/a	1.8	a	0.3	a	1	a
Chateau	6	oz/a	1.5	a	1	a	0.3	a
Chateau	12	oz/a	3.5	a	0.3	a	0.7	a
Chateau + SP1171	6 +12.8	oz +fl oz/a	3.5	a	2.2	a	0	a
Chateau + SP1171	6 + 19.2	oz/a + fl oz/a	1.5	a	1.3	a	0.7	a

Treatments applied January 20, 2015. Means followed by same letter do not significantly differ (P=.05, Tukey's HSD)

Table 8. Postemergence weed control in an almond orchard trial conducted near Wasco, CA in spring 2014. (Moretti, Watkins, and Hanson)

				----- 15 DAT -----		---------------------- 28 DAT -----------------------			
				Annual bluegrass	*Hairy fleabane*	*Jungle-rice*	*Annual bluegrass*	*Hairy fleabane*	*Total biomass*
				-----------------	-----------------	---------- % ----------	-----------------	-----------------	*g/m sq*
1	untreated control			0	0	0	0	0	137.1
2	Roundup Powerrmax	1	lb ae/a	100	30	65	100	67	23.8
	AMS	2	pt/a						
	NIS	0.25	% v/v						
3	Roundup Powerrmax	44	fl oz/a	98	73	90	100	93	4.3
	AMS	2	pt/a						
	NIS	0.25	% v/v						
4	Rely 280	48	fl oz/a	100	100	87	98	100	1.4
	AMS	2	pt/a						
5	Rely 280	82	fl oz/a	100	100	91	98	87	0.7
	AMS	2	pt/a						
6	Gramoxone SL	1.25	pt/a	100	0	92	100	50	52.5
	NIS	0.25	% v/v						
7	Gramoxone SL	4	pt/a	100	0	92	100	78	7.9
	NIS	0.25	% v/v						
8	Matrix	2	oz/a	60	50	86	98	72	42.0
	AMS	2	pt/a						
	NIS	0.25	% v/v						
9	Roundup Powerrmax	1	lb ae/a	100	88	98	67	93	0.1
	Matrix	2	oz/a						
	AMS	2	pt/a						
	NIS	0.25	% v/v						
10	Roundup Powerrmax	1	lb ae/a	100	53	100	100	86	64.9
	Pindar GT	1.5	pt/a						
	AMS	2	pt/a						
	NIS	0.25	% v/v						
11	Chateau	6	oz/a	100	75	100	100	66	0.1
	NIS	0.25	% v/v						
	Roundup Powerrmax	1	lb ae/a						
	AMS	2	pt/a						
12	Poast	1.5	pt/a	0	0	0	33	27	217.8
	COC	1	% v/v						
13	Poast	1.5	pt/a	100	40	98	67	95	74.7
	COC	1	% v/v						
	Roundup Powerrmax	1	lb ae/a						
	AMS	2	pt/a						
14	Roundup Powerrmax	1	lb ae/a	100	75	100	100	92	0.1
	Matrix	4	oz/a						
	Ammonium Sulfate	2	pt/a						
	NIS	0.25	% v/v						
15	Roundup Powerrmax	1	lb ae/a	100	34	97	100	98	12.6
	AMS	2	pt/a						
	NIS	0.25	% v/v						
	Goal 2XL	0.125	lb ai/a						
LSD (P=.05)				***1***	***44***	***26***	***41***	***50***	***115.3***

* All treatments applied POST on April 23, 2014.

Table 3. Mortality of glyphosate-paraquat-resistant (GPR) and -susceptible (GPS) hairy fleabane 28 d after herbicide treatment in greenhouse experiments.

Treatments[a]	Rate[b]	Mortality: Experiment 1 and 2[c] Resistant	Susceptible		Experiment 3 Resistant	Susceptible	
	g ae ha^{-1}	%			%		
Nontreated control	n/a	0	0	NS[d]	0	0	NS
Glyphosate	1,100	8	50	*	0	50	*
2,4-D	1,090	17	17	NS	50	50	NS
Glufosinate	1,050	67	67	NS	100	100	NS
Saflufenacil	48.8	100	100	NS	100	100	NS
Carfentrazone	15.5	8	8	NS	0	0	NS
Glyphosate + 2,4-D	1,100 + 1,090	58	92	*	100	100	NS
Glyphosate + glufosinate	1,100 + 1,050	75	92	NS	100	100	NS
Glyphosate + saflufenacil	1,100 + 48.8	100	92	NS	100	100	NS
Glyphosate + carfentrazone	1,100 + 15.5	42	100	*	17	17	NS
Glufosinate + 2,4-D	1,050 + 48.8	100	100	NS	100	100	NS
Glufosinate + saflufenacil	1,050 + 1,090	100	100	NS	100	100	NS
Paraquat	1,400	8	100	*	0	83	*
Glyphosate fb paraquat	1,100 fb 1,400	0	92	*	0	100	*

[a] Ammonium sulfate at 5% w/v was added to all treatments. Non-ionic surfactant at 0.5% v/v was added to treatments including glyphosate, 2,4-D, carfentrazone, or paraquat. Methylated seed oil was added at 1% v/v to treatments that included saflufenacil.

[b] Rate expressed as active ingredient or acid equivalent as appropriate.

[c] Treatment means were pooled for experiments 1 and 2 ($n=12$) conducted in November and December 2011 but not experiment 3 conducted in September 2012 ($n=6$).

[d] Abbreviations: NS, non-significant at the 0.05 probability level; *, significant differences between populations for each herbicide treatment according to likelihood ratio test ($P < 0.05$); fb, followed 14 d later by.

Table 4. Glyphosate-resistant (GR) hairy fleabane biomass, density, and level of control 28 d after herbicide treatments in two[a] almond orchards experiments in Merced County, CA in 2012.

Treatments[b]	Rate[c]	Biomass[d]	Density	Control
	g ae or ai ha^{-1}	g m^{-2}	plants m^{-2}	%
Nontreated control	n/a	596 a	107 a	0 d
Glyphosate	1,100	387 a	109 a	3 cd
2,4-D	1,090	0 c	1 c	85 ab
Glufosinate	1,050	5 c	11 bc	88 a
Saflufenacil	48.8	2 c	8 bc	96 a
Carfentrazone	15.5	273 ab	90 ab	1 d
Glyphosate + 2,4-D	1,100 + 1,090	1 c	1 bc	99 a
Glyphosate + glufosinate	1,100 + 1,050	0 c	2 c	93 a
Glyphosate + saflufenacil	1,100 + 48.8	3 c	5 c	92 a
Glyphosate + carfentrazone	1,100 + 15.5	399 a	118 a	14 c
Glufosinate + 2,4-D	1,050 + 48.8	0 c	0 c	95 a
Glufosinate + saflufenacil	1,050 + 1,090	0 c	2 c	100 a
Paraquat	1,400	0 c	0 c	99 a
Glyphosate fb paraquat	1,100 fb 1,400	0 c	1 c	98 a
Glyphosate + penoxsulam/oxyfluorfen	1,100 + 15/740	152 bc	49 abc	54 b
Glyphosate + flumioxazin	1,100 + 23	203 ab	49 abc	11 c
Paraquat + flumioxazin	1,400 + 23	0 c	0 c	100 a
Glyphosate + rimsulfuron	1,100 + 30	182 ab	60 abc	43 b
Glyphosate + rimsulfuron + saflufenacil	1,100 + 30 + 48.8	1 c	6 c	94 a

[a] Treatment means of two field trials (n=8) are combined.

[b] Ammonium sulfate at 5% w/v was added to all treatments. Non-ionic surfactant at 0.5% v/v was added to treatments that included glyphosate, 2,4-D, carfentrazone, or paraquat. Methylated seed oil was added at 1% v/v to treatments that included saflufenacil. Treatments that included 2,4-D were applied only to one location in 2012 ($n=4$). Abbreviation used: fb, followed 14 d later by.

[c] Rate expressed as active ingredient or acid equivalent as appropriate.

[d] Means followed by same letter within a column are not statistically different according to Tukey's test ($P < 0.05$).

Figure 2. Screen captures of tables from an in-press journal publication entitled "Postemergence control of glyphosate/paraquat resistant hairy fleabane (Conyza bonariensis) in tree nut orchards in the Central Valley of California" (Moretti, Shrestha, Kembree, and Hanson).

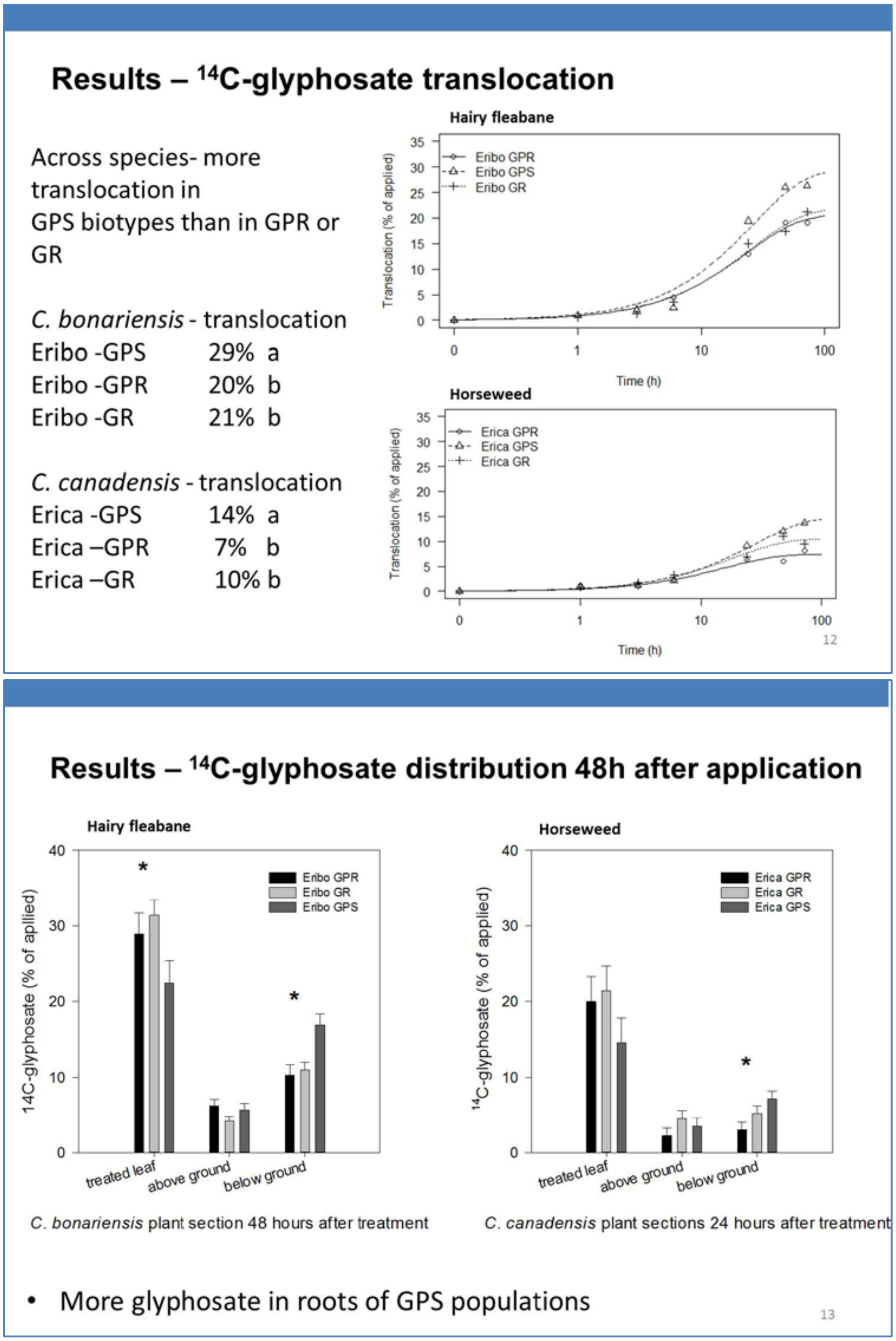


Figure 3. Representative data on the translocation of radio-labeled glyphosate in glyphosate-resistant and –susceptible hairy fleabane. (Moretti and Hanson).

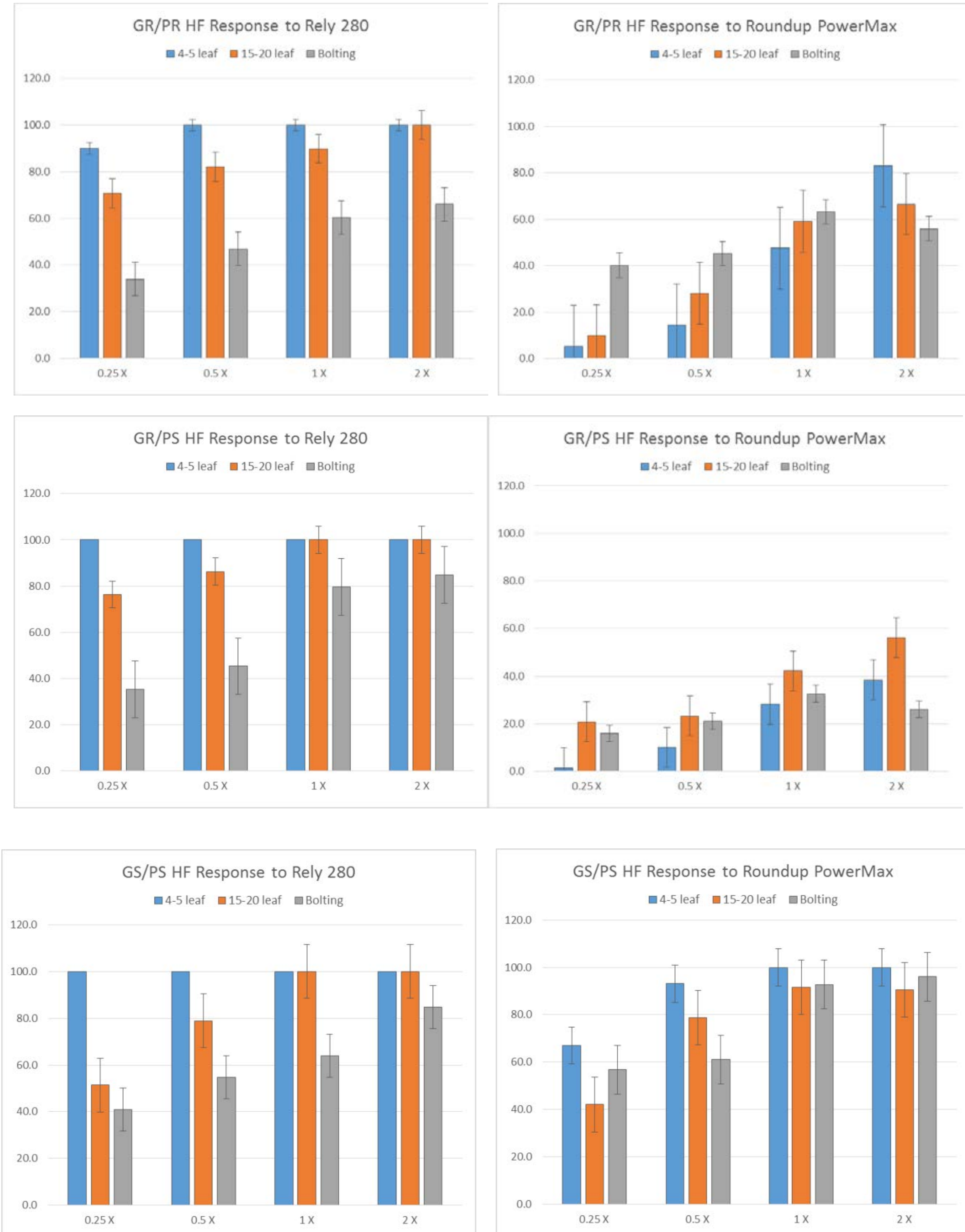


Figure 4. Examples of regrowth responses of hairy fleabane treated a at the small rosette, large rosette, and bolting stages with either Rely 280 (left) or Roundup Powermax (right) the top, middle and lower figures are glyphosate-resistant, glyphosate/paraquat resistant, and susceptible populations, respectively. (Sosnoskie and Hanson).

Figure 5. Response to increasing glyphosate doses of a susceptible (S) and resistant (R) population of Junglerice collected from the Central Valley of California. Populations were sprayed in dose response experiments using a range of glyphosate rates from 0 to 3480 g.a.i.ha^{-1}. (Morran, Moretti, Fischer, and Hanson)

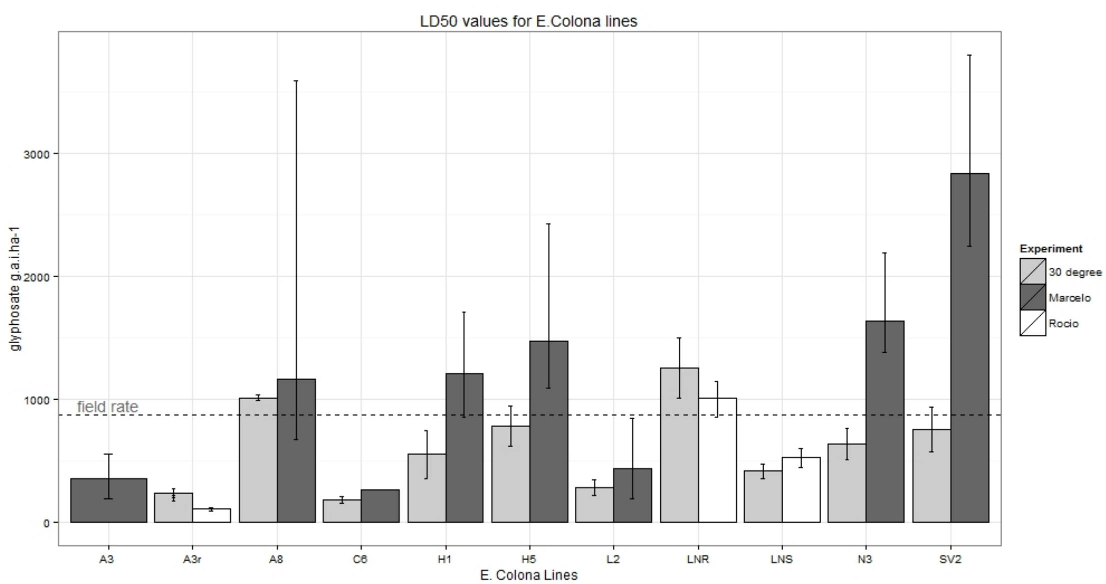


Figure 6. Glyphosate LD50 values for F3 single-seed lines derived from populations collected from the Central Valley of California. Dose response experiments were carried out in a controlled temperature growth chamber at 35^0C/28^0C and in greenhouse conditions over a summer growing period with temperatures ranging from 25^0C to 35 ^{0}C. Error bars denote 95% confidence intervals. (Morran, Moretti, Fischer, and Hanson).

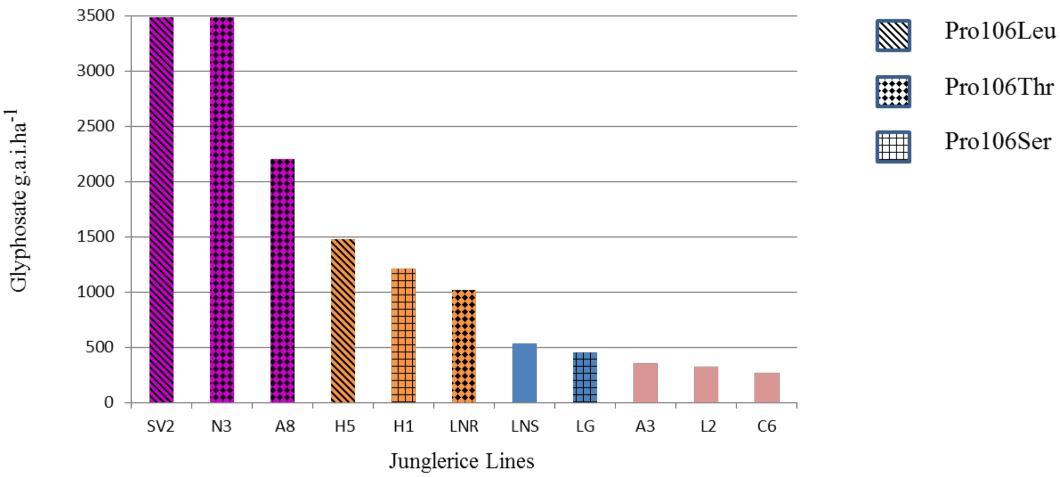


Figure 7. Glyphosate-resistant jungle rice plants from the Central Valley have different EPSPS mutations that are associated with varying levels of glyphosate resistance at the whole plant level. Data indicate GR50 levels in greenhouse experiments on populations derived from previous field collections. (Morran, Moretti, Fischer, and Hanson)

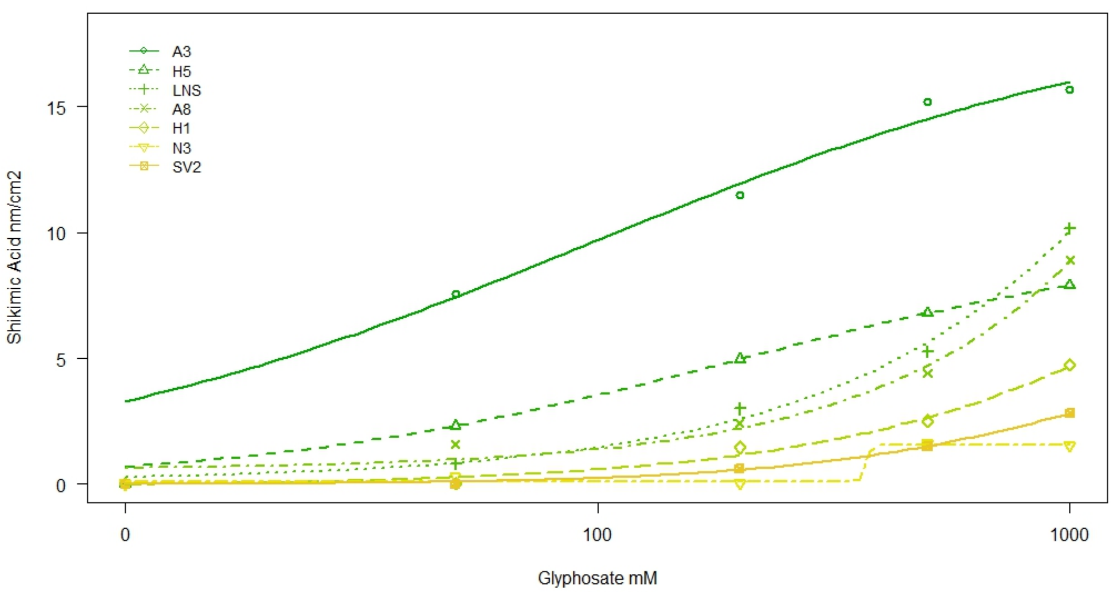


Figure 8. Glyphosate-resistant junglerice populations respond differently to glyphosate as measured by accumulation of shikimic acid. This suggests that there may be more than one mechanism of resistance in California populations. (Morran, Moretti, Fischer, and Hanson)

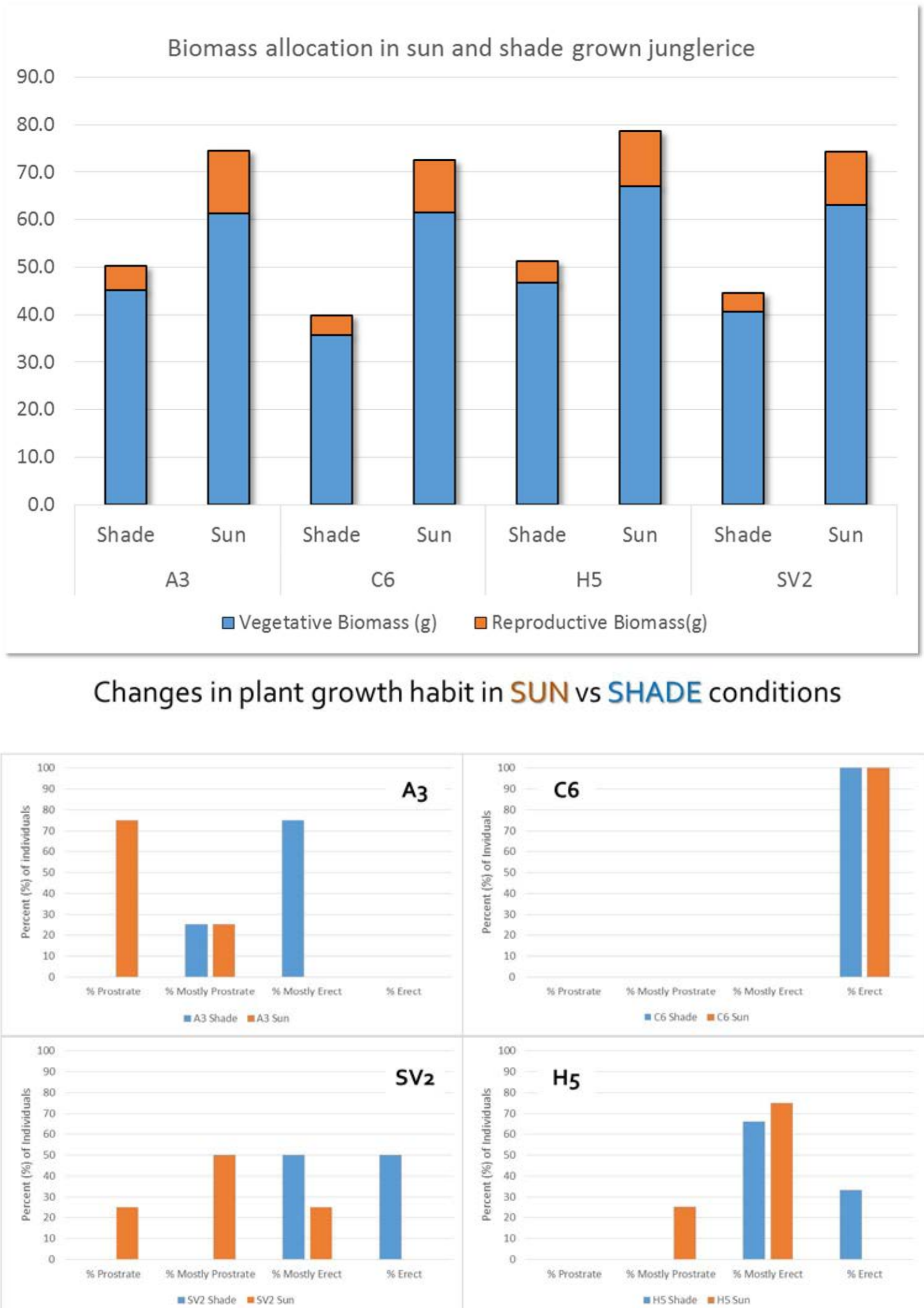


Figure 9. Glyphosate-resistant junglerice populations from various regions of California have different growth habits and responses to environmental cues (e.g. shade). Current research is ongoing to determine if or how this may be related to resistance to herbicides or other stresses and if the resistant populations are also more invasive than the wild types. (Sosnoskie, Morran, and Hanson).

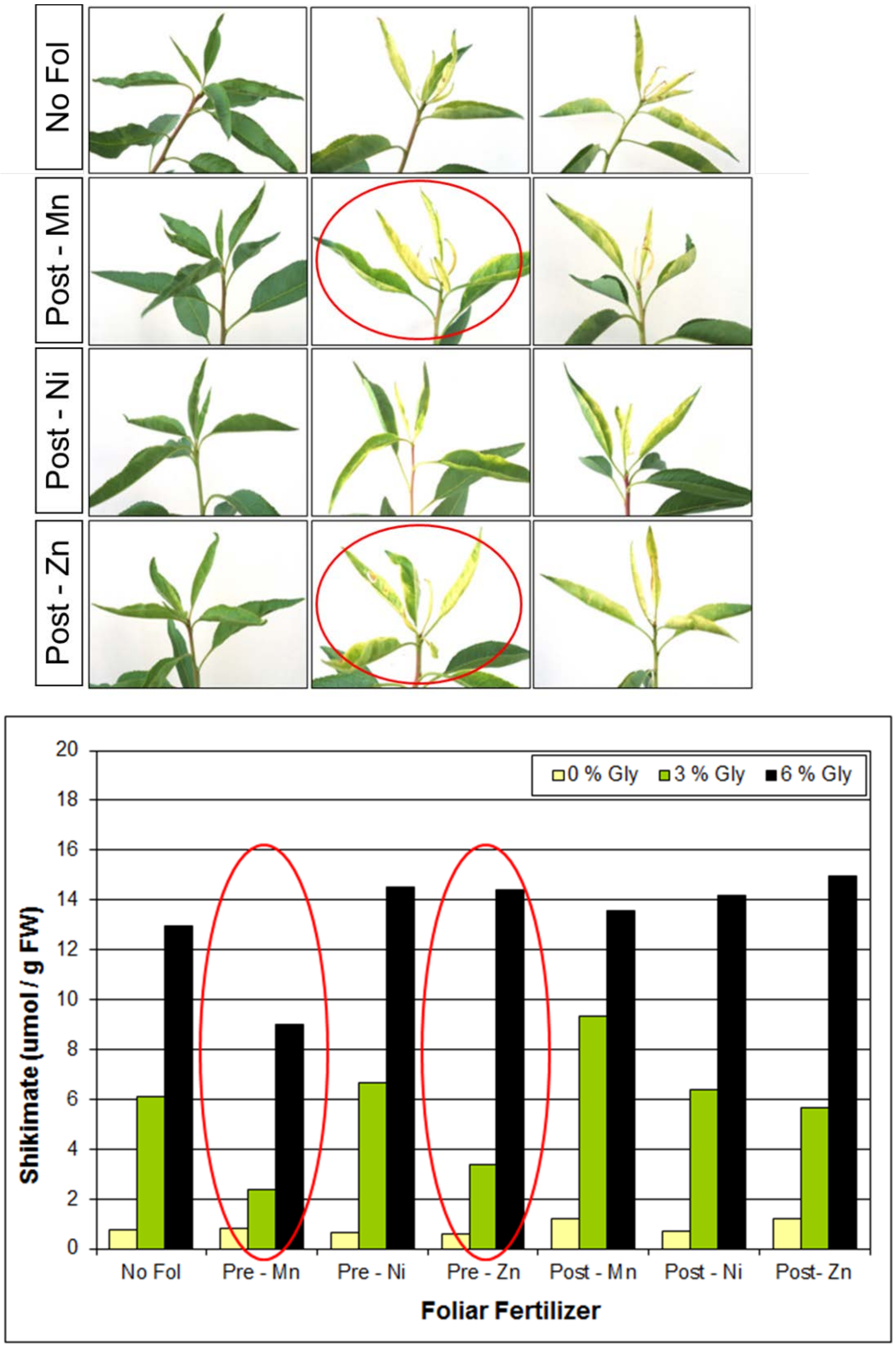
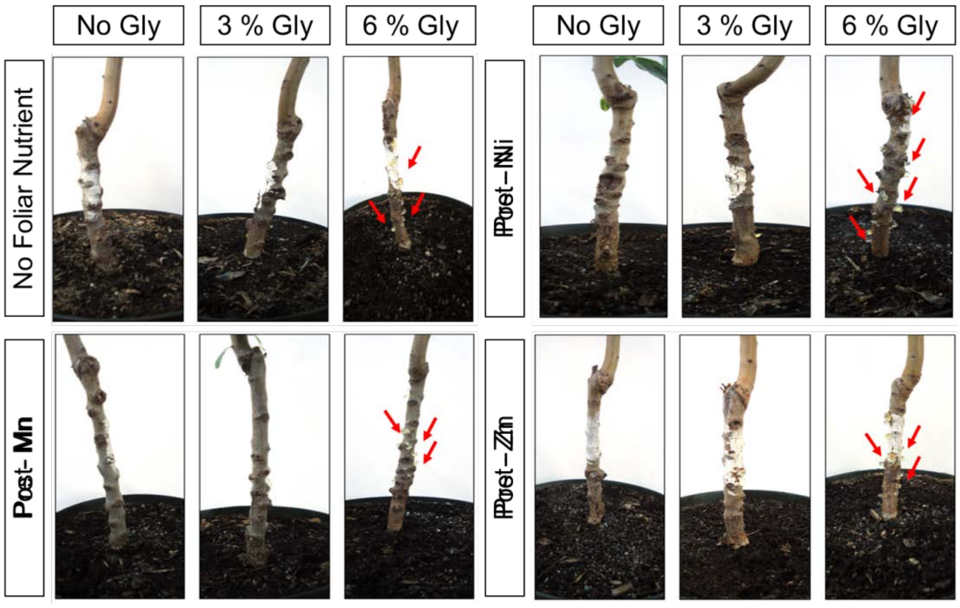


Figure 10. Examples of current research on the interaction between foliar micronutrients and simulated glyphosate drift. Top photo shows chlorosis on new almond growth 14 days after exposure to glyphosate at 3% and 6% of a common orchard use rate and the effects of micronutrients applied five days before or after glyphosate. This work is not directly funded by the Almond Board of California. (Yilidiz Kutman, Brown, and Hanson).



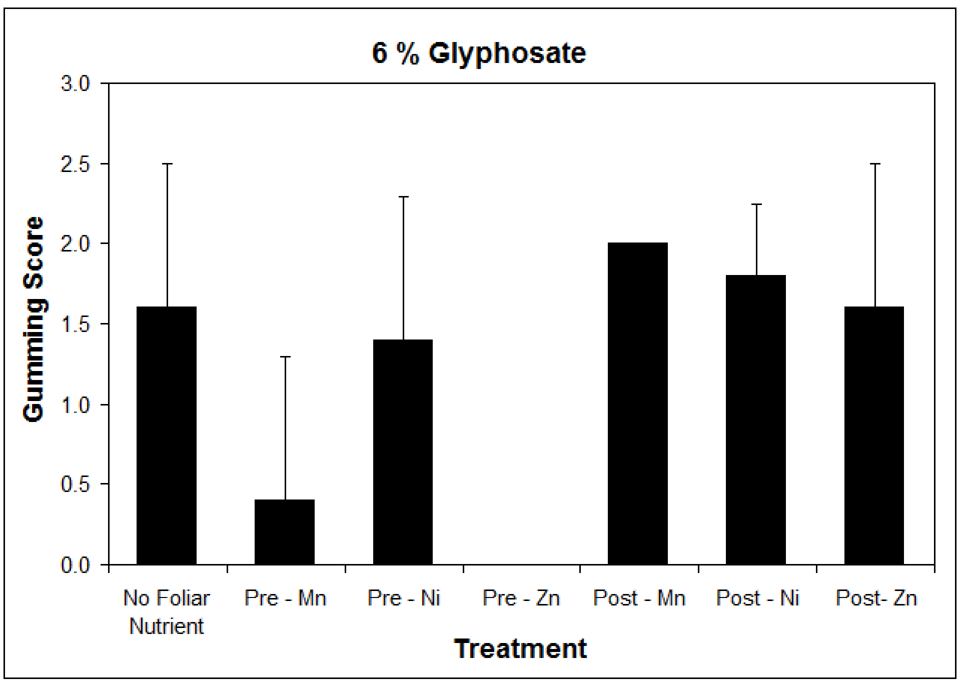


Figure 11. Examples of current research on the interaction between foliar micronutrients and simulated glyphosate drift. The photo shows an unexpected gumming at the graft union (Nonpareil on Lovell) several weeks after simulated glyphosate drift. The lower figures show gumming ratings from the same treatments. This work is not directly funded by the Almond Board of California. (Yilidiz Kutman, Brown, and Hanson).

Figure 12. Examples of herbicide symptomology demonstrations use to help troubleshoot crop injury issues. Images are also being used to further populate online support tools such as the UC-IPM Herbicide Symptoms database available online at http://herbicidesymptoms.ipm.ucanr.edu/index.cfm.