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Safety and efficacy of herbicides in bearing avocados

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Executive Summary

Currently, there are only 10 herbicide active ingredient registered for use on bearing avocado in California. Of these, paraquat is a restricted use herbicide, glyphosate is under increasing political scrutiny, and simazine has been found in ground water in California and will likely be cancelled. To determine if additional herbicides could be registered in avocado, we conducted studies evaluating the phytotoxicity and efficacy of several herbicides, currently registered in citrus, for use on bearing avocado in multiple locations. Treatments included caprylic/capric acid, clethodim, flumioxazin, glufosinate, glyphosate, indaziflam, isoxaben, oxyfluorfen, pendimethalin, rimsulfuron, salfufenacil, simazine, and S-metolachlor. Weed densities and avocado phytotoxicity from simulated spray drift were monitored at 1, 2, 4, and 8 weeks after treatment (WAT) during the fall and spring. Glufosinate and glyphosate controlled 95-100% of the weeds for up to 8 WAT in both seasons. However, in the fall treatment, glufosinate and glyphosate drift caused significant phytotoxicity (71% and 75% respectively). Phytotoxicity from pendimethalin, isoxaben and saflufenacil (29, 38, and 23% respectively) was evident only at 8 WAT. Indaziflam also gave excellent weed control in the fall and spring with some minor phytotoxicity to the foliage in the first weeks after application, however, phytotoxicity symptoms diminished to 15% by 8 WAT. Rimsulfuron, similarly, had exceptional weed control in both spring and fall throughout 8 WAT and exhibited little to no phytotoxicity to the avocado foliage. Preliminary results indicated that clethodim, indaziflam and rimsulfuron have good potential for weed control in bearing avocado. Similarly, glyphosate and glufosinate also provided excellent control, but can be injurious to bearing avocado trees with spray drift. Based on trial results, clethodim and rimsulfuron were submitted to the federal IR4 program which is for registration of pesticides for minor crops IR4. These two herbicides are currently in residue testing, which is required for registration.

Introduction and Background

There are currently only 10 herbicide active ingredients registered in California for use in bearing avocado groves. Growers rely heavily on glyphosate, which is under political scrutiny, paraquat is a restricted use herbicide and with probable registration loss of simazine due to significant ground water contamination issues California avocado growers need of alternative herbicides. A comprehensive evaluation of herbicides for safety and efficacy in bearing avocado orchards has been studied using herbicides currently registered for citrus (the only similar subtropical orchard crop in the state), but not in avocado. This study has provided critical, science-based information to the California Avocado Commission and herbicide registrants to pursue additional product labels.

The objectives of this study were:

1. Determine the safety and efficacy of herbicides currently registered for citrus for use on bearing avocado.
2. Identify both pre and post emergent alternatives to glyphosate and simazine

To account for differences in soil type and climate, the research trials were established in two distinct growing regions (Ventura and Riverside County). Herbicides were applied in spring and fall to capture differences in efficacy in controlling different seasonal weed spectrums and safety for different seasonal phenology in avocado groves. Special attention was paid to immediate and cumulative phytotoxic effects. The study has been repeated in two consecutive years at each site to address inter-year variations in weather and other factors, especially rainfall. Special consideration has been given to products that can be applied with backpack or handheld sprayers, herbicides with suitable restricted-entry and preharvest intervals, herbicide product cost, duration of efficacy, and effectiveness for control of priority management weed species.

Field studies

We reviewed and selected pre- and post-emergence herbicide products currently labeled for citrus in California, since these products have the benefit of being approved for use in another subtropical orchard crop and have known weed control spectra. These included indaziflam (Alion), pendimethalin (Prowl H2O), rimsulfuron (Matrix), S-metolachlor (Pennant Magnum), saflufenacil (TreeVix), isoxaben (Gallery), and glufosinate-ammonium (Forfeit). Herbicide products currently labeled for bearing avocado orchards included: oxyfluorfen (Goal), flumioxazin (Chateau), simazine (Princep), glyphosate (Roundup), prodiamine (Proclipse), carfentrazone-ethyl (Shark), and caprylic acid (Suppress). Table 1 lists the type and rates of herbicides tested.

To account for differences in soils and climate, research sites included the UC Hansen Research and Extension Center (HAREC) in Santa Paula on 15-yr-old Hass avocado and Citrus Research Center-Agricultural Experiment Station (UCR) at UC Riverside on 2-yr-old Hass avocado. The experiment was repeated four time (two fall and two spring applications) at each location, and data was collected for weed control and herbicide phytotoxicity to avocados over a period of 8-10 weeks. Herbicides were applied to orchard floor adjacent to the tree skirts to evaluate efficacy under typical grove conditions, as well as for safety regarding potential uptake by shallow avocado roots. Additionally, tree foliage was sprayed directly to allow for simulation of spray drift and determination of phytotoxicity. The plots at each site were different depending on tree spacing, but approximately 40 to 60 sq ft. Applications were made according to label directions for rate and carrier volume using a calibrated CO_2-propelled backpack sprayer with the applicator wearing the appropriate PPE. The spray boom was oriented horizontally for ground application and vertically for foliage application. Following treatment applications, herbicides were incorporated with simulated rainfall using a temporary sprinkler system to apply 0.5 inch of water. The second year of the UCR site, the spring application was incorporated by rain. At all sites weeds were 2-4 inches tall when herbicides treatments were applied. Year 1 treatments were made in October/November 2019 and February/May 2020. Year 2, treatments were made at each location in November/December 2020 and March/April 2021. Evaluations for efficacy and safety were conducted at 1, 2, 4, and 8 wk after treatment for post-emergence herbicides. Efficacy was evaluated for each weed species. If weed densities were low, counts were made by species in each plot. Tree injury was evaluated on a 1 (none) - 10 (dead tissue) scale for each plot as simulated overspray applications.

Each treatment was replicated four times in a randomized complete block design at each site. Data was analyzed using mixed model ANOVA to model response variables of efficacy and safety separately, with replications as random effects, and treatment, timing, location, and year as fixed effects. Tukey's HSD has used to identify differences in least squares means of response variables.

In 2022, with the ultimate goal of submitting herbicides for registration, we conducted an additional trial to further test the superior performing post-emergent herbicides to more comprehensibly determine phytotoxicity on avocado before submitting to IR4 for registration. For this, we established post-emergent herbicides as well as a common tank-mix used in citrus. Treatments are listed in Table 2. The trials were located at The Hansen Research and Extension Center (HAREC) in Santa Paula on ~19-yr-old avocado and at UC Riverside Citrus Research Center-Agricultural Experiment Station (CRC-AES) on 4-yr-old avocados. Treatments were applied in June 2022 in a randomized complete block design using 4 replicates. Treatments were made along the row of avocado immediately adjacent to the tree skirt. This was done to emulate grower practices where tree skirts many receive drift or direct spraying of herbicides. Plots were 20 ft x 3.33 ft on each side of the tree.

Herbicide applications were made using calibrated CO_2 backpack sprayers using the rates and carrier volumes (40 GPA) listed on labels for citrus. Phytotoxicity ratings at both UCR and HAREC were on a 1-10 scale with 1=healthy and 10=completely necrotic. For HAREC, treatments were applied on 6/22/22 and phytotoxicity was rated at 7, 14, 21 and 28 days after treatment (DAT). For HAREC, no surfactants were used with the herbicides so that the trial reproduced prior tests; however, UCR followed the protocols established by IR4 for similar studies and included the registrant's recommendations for surfactants. For the UCR trial treatments were applied on 6/25/22 and phytotoxicity was rated 7, 14 and 28 DAT. In addition to phytotoxicity ratings, a photolog was maintained to show the progression and severity of phytotoxicity. The treatments were applied.

Table 1. Rates and application timing for herbicides tests on avocado in Riverside and Santa Paula in 2020-21.

No.	Pre/Post emergent	Product	Active Ingredient	Rate
1			Untreated	
2	Post	Forfeit 280	Glufosinate	56 oz/A
3	Post	Round up	Glyphosate	3.8 lbs a.i./A, 7%
4	Post	Suppress	Caprylic Acid	9%
5	Post	Shadow 3EC	Clethodim	16 oz/A
6	Pre/Post	Treevix	Saflufenacil	1 oz/A
7	Pre/Post	Chateau EZ	Flumioxazin	12 oz/A
8	Pre/Post	Goaltender	Oxyfluorfen	3 pt/A
9	Pre	Alion	Indaziflam	6.5 oz/A
10	Pre	Matrix SB	Rimsulfuron	4 oz/A
11	Pre	Princep 4L	Simazine	4.4 lb/A
12	Pre	Pennant Magnum	S-metolachlor	2 pt/A
13	Pre	Prowl H_2O	Pendimethalin	6.3 qt/A
14	Pre	Gallery	Isoxaben	1.33 lb/A

Table 2. Rates and tank mixtures used for 2022 herbicide tests on avocado in Riverside and Santa Paula.

No.	Treatment	Rate	Surfactant*
1	Untreated		
2	Saflufenacil	1 oz/A	5.2 lb/A Ammonium Sulfate (AMS) and 1% Methalated Seed Oil (MSO)
3	Glufosinate	56 oz/A	5.2 lb/A AMS and 1% MSO
4	Glufosinate+Saflufenacil	56 oz/A+1 oz/A	5.2 lb/A AMS and 1% MSO
5	Glyphosate	3.8 lbs a.i./A, 7%	5.2 lb/A AMS and 1% MSO

*Surfactants were used at UCR field trial but not Ventura field trial

Results

<u>2020 and 2021 Spring and Fall trials:</u>

The major weeds species were tumble pigweed (*Amaranthus albus*), common purslane (*Portulaca oleracea*), sow thistle (*Sonchus hierrensis),* cheeseweed/mallow (*Malva parviflora*), stinging nettle (*Urtica urens*) and hairy fleabane (*Erigeron bonariensis*). Weed densities and phytotoxicity were monitored at 1, 2, 4, and 8 weeks after application. A photolog was maintained to show the progression of damage.

For percent weed mortality at the UCR location, there was a significant interaction ($P<0.05$) between the season and treatments, therefore, data were separated by seasons for the different weeks after treatment (WATs) sampling (Table 3 and 5) and reanalyzed. There was also a season by treatment interaction at this site for phytotoxicity on the avocado plants, so data were separated for the two seasons at each sampling date and reanalyzed (Table 4 and 6). For the HAREC location, there was no season by treatment interaction ($P>0.05$), so data were combined for the two seasons and analyzed. The results below are phytotoxicity of the treatments averaged over the two seasons. Means were separated by Fisher's Least Significant Difference (LSD) test when the ANOVA was significant at the 0.05 level.

During Spring and Fall at the UCR location, glyphosate and glufosinate had excellent weed control up to 8 WAT. Followed by saflufenacil, simazine, and indaziflam in the fall. However, injury from glyphosate and glufosinate were observed throughout 8 WAT. However, with glufosinate, the buds remained viable after injury and eventually produced new leaves (images at 8 WAT). In the Spring, caprylic acid had caused damage to foliage but also had poor weed control overall. At the Hansen location, glyphosate and glufosinate had excellent weed control all the way to 8 WAT and visual observations concluded that damage also occurred on scaffold foliage, however glufosinate damage slowly subsided by the 8 WAT.

Results indicate that there are potential herbicide candidates that could possibly be used in avocado as an alternative to glyphosate or to help decrease the reliance on glyphosate. This project is on track to yield information that will inform growers on which herbicides could be possibly used in an avocado orchard for weed control and that will the least amount of damage to the tree.

Data presented in tables 3-6 are representative of both locations. One consistent result we saw at HAREC and was less pronounced but noticeable at UCR was that protoporphyrinogen oxidase (PPO) inhibitor herbicides, (which are mainly contact, foliar-applied herbicides that have limited translocation in the xylem), such as oxyfluorfen and flumioxazin, provided good control of germinating weeds and small germinated weeds (but not established weeds). Neither oxyfluorfen and flumioxazin were as good as glyphosate or glufosinate but they performed better than most other treatments. This is an important point since oxyfluorfen and flumioxazin are registered for avocado and may be somewhat underutilized. Oxyfluorfen and flumioxazin could play a greater role in weed control if the scrutinized herbicides get less use or are pulled out. These are not a standalone herbicide program but they are components of weed IPM.

Table 3. Percent weed control in Fall 2020/2021 at 1, 2, 4 and 8 weeks after treatment (WAT) at UCR.

No.	Treatment	Rate	1 WAT	2 WAT	4 WAT	8 WAT
1	S-metolachlor	2 pt/A	1.3 e	18.8 def	43.8 de	57.8 bcde
2	Flumioxazin	12 oz/A	7.0 cde	12.5 ef	26.3 ef	54.8 bcde
3	Simazine	4 lb/A	11.3 bcd	25.0 de	52.5 cde	76.8 abc
4	Rimsulfuron	4 oz/A	72.0 a	83.5 ab	92.3 a	75.0 abcd
5	Oxyfluorfen	3 pt/A	11.3 cde	31.3 de	38.8 def	52.5 cde
6	Indaziflam	6.5 oz/A	80.8 a	89.5 a	77.5 abc	68.3 bcd
7	Pendimethalin	6.3 qt/A	31.3 b	40.0 cd	48.3 cde	42.5 def
8	Isoxaben	1.33 lb/A	15.0 bcd	40.0 cd	44.5 de	56.3 bcde
9	Saflufenacil	1 oz/A	23.0 b	33.0 d	60.0 bcd	67.5 bcd
10	Clethodim	16 oz/A	3.3 de	6.3 fg	8.8 fg	16.3 fg
11	Caprylic Acid	9%	19.5 bc	28.3 de	32.5 def	26.3 ef
12	Glufosinate	56 oz/A	30.0 b	61.3 bc	79.3 ab	97.3 a
13	Glyphosate	3.8 lbs a.i./A, 7%	57.5 a	71.3 ab	81.3 ab	84.3 ab
14	Untreated		0.0 e	0.0 g	0.0 g	0.0 g
P-value			<0.0001	<0.0001	<0.0001	<0.0001

Table 4. Phytotoxicity of the herbicide treatments on the avocado trees expressed in Fall 2020/2021 at 1, 2, 4 and 8 weeks after treatment (WAT) at UCR.

No.	Treatment	Rate	1 WAT	2 WAT	4 WAT	8 WAT
1	S-metolachlor	2 pt/A	0.0 c	0.0 d	0.0 d	1.3 bc
2	Flumioxazin	12 oz/A	0.0 c	0.0 d	0.1 d	0.0 c
3	Simazine	4 lb/A	0.0 c	0.0 d	0.0 d	1.3 bc
4	Rimsulfuron	4 oz/A	0.0 c	0.1 d	0.1 d	0.0 c
5	Oxyfluorfen	3 pt/A	0.0 c	0.0 d	0.0 d	0.1 c
6	Indaziflam	6.5 oz/A	0.7 bc	1.0 cd	1.0 cd	1.0 bc
7	Pendimethalin	6.3 qt/A	0.1 c	1.8 abc	0.0 d	0.1 c
8	Isoxaben	1.33 lb/A	0.4 bc	1.6 bc	1.7 bc	0.8 bc
9	Saflufenacil	1 oz/A	1.0 b	2.3 ab	2.5 ab	2.3 ab
10	Clethodim	16 oz/A	0.0 c	0.0 d	0.0 d	0.1 c
11	Caprylic Acid	9%	0.0 c	0.8 cd	2.1 abc	1.1 bc
12	Glufosinate	56 oz/A	1.1 b	2.5 ab	3.3 a	3.1 a
13	Glyphosate	3.8 lbs a.i./A, 7%	2.8 a	3.0 a	3.0 ab	4.0 a
14	Untreated		0.0 c	0.0 d	0.0 d	0.0 c
P-value			<0.0001	<0.0001	<0.0001	<0.0001

Means within a column followed by the same letter are not significantly different at the Fisher's LSD test at 0.05 level.

Table 5. Percent weed control in Spring 2021 at 1, 2, 4 and 8 weeks after treatment (WAT) at UCR.

No.	Treatment	Rate	1 WAT	2 WAT	4 WAT	8 WAT
1	S-metolachlor	2 pt/A	39.5ab	34.3bcd	30.0cde	28.0efg
2	Flumioxazin	12 oz/A	36.3abc	38.3abcd	53.8bc	68.8bc
3	Simazine	4 lb/A	53.3ab	47.8abc	39.5cde	22.8g
4	Rimsulfuron	4 oz/A	55.5ab	46.3abc	42.0cd	36.0defg
5	Oxyfluorfen	3 pt/A	71.0a	65.0a	62.3abc	50.8cde
6	Indaziflam	6.5 oz/A	45.8ab	43.8abc	46.3cd	46.3cdef
7	Pendimethalin	6.3 qt/A	28.8bc	22.5cd	16.3de	13.8g
8	Isoxaben	1.33 lb/A	52.5ab	45.0abcd	31.0cde	28.8fg
9	Saflufenacil	1 oz/A	53.3ab	48.8abc	45.0cde	61.3bcd
10	Clethodim	16 oz/A	3.8cd	8.8de	8.8ef	18.8g
11	Caprylic Acid	9%	20.0bcd	30.0bcd	33.8cde	30.0efg
12	Glufosinate	56 oz/A	32.5abc	72.3a	85.5a	93.8a
13	Glyphosate	3.8 lbs a.i./A, 7%	46.3ab	68.8a	78.8ab	79.5ab
14	Untreated		0.0d	0.0e	0.0f	0.0h
P-value			<0.0001	<0.0001	<0.0001	<0.0001

Table 6. Phytotoxicity of the herbicide treatments on the avocado trees expressed in Spring 2020/2021 at 1, 2, 4 and 8 weeks after treatment (WAT) at UCR.

No.	Treatment	Rate	1 WAT	2 WAT	4 WAT	8 WAT
1	S-metolachlor	2 pt/A	0.0 c	0.5 c	1.0 bc	0.0 c
2	Flumioxazin	12 oz/A	0.0 c	0.5 c	1.0 bc	0.0 c
3	Simazine	4 lb/A	0.3 c	0.6 c	1.4 bc	0.0 c
4	Rimsulfuron	4 oz/A	0.0 c	0.0 c	1.0 bc	0.0 c
5	Oxyfluorfen	3 pt/A	0.0 c	0.8 c	1.8 bc	0.0 c
6	Indaziflam	6.5 oz/A	0.0 c	0.0 c	0.3 c	0.0 c
7	Pendimethalin	6.3 qt/A	0.0 c	0.0 c	0.0 c	0.0 c
8	Isoxaben	1.33 lb/A	1.0 bc	1.9 bc	1.8 bc	0.0 c
9	Saflufenacil	1 oz/A	0.0 c	0.0 c	0.5 c	0.0 c
10	Clethodim	16 oz/A	0.3 c	1.0 c	0.0 c	0.0 c
11	Caprylic Acid	9%	0.0 c	3.5 ab	3.5 ab	1.5 b
12	Glufosinate	56 oz/A	1.8 b	5.2 a	5.8 a	5.4 a
13	Glyphosate	3.8 lbs a.i./A, 7%	4.9 a	5.3 a	5.5 a	5.4 a
14	Untreated		0.0 c	0.0 c	0.0 c	0.0 c
P-value			<0.0001	<0.0001	<0.0001	<0.0001

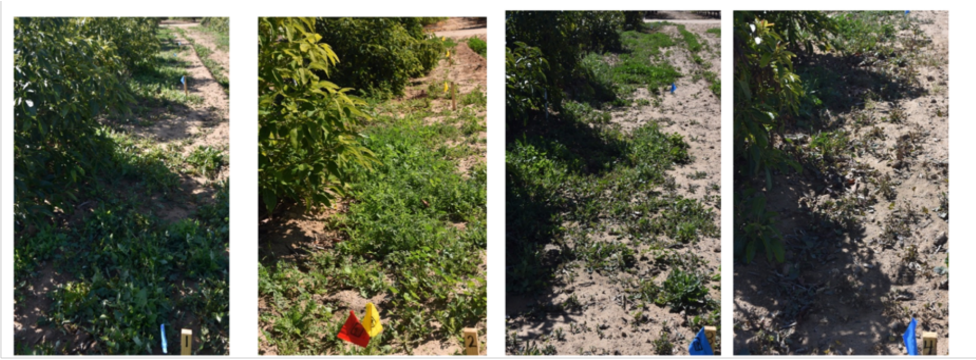
Means within a column followed by the same letter are not significantly different at the Fisher's LSD test at 0.05 level.

Table 7. Phytotoxicity of the herbicide treatments on the avocado trees expressed in Fall and Spring of 2020/2021 at 1, 2, 4 and 8 weeks after treatment (WAT).

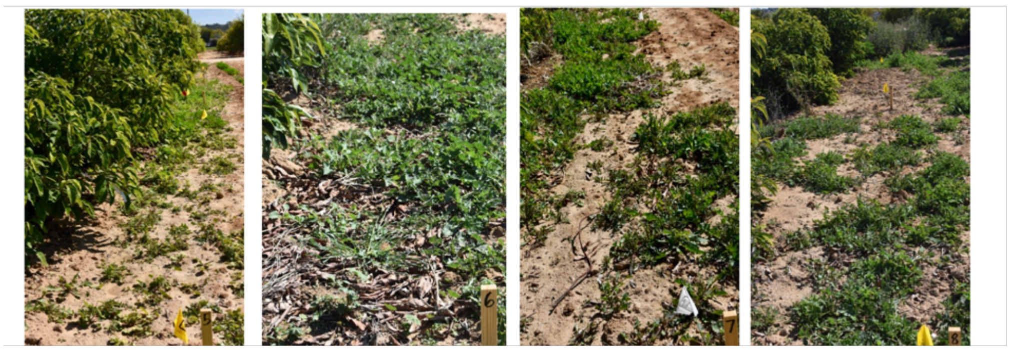
No.	Treatment	Rate	1 WAT	2 WAT	4 WAT	8 WAT
1	S-metolachlor	2 pt/A	0.9 cd	1.5 cd	1.3 bc	1.3 c
2	Flumioxazin	12 oz/A	0.8 cd	1.2 d	1.2 bc	1.1 c
3	Simazine	4 lb/A	0.8 cd	1.3 cd	1.2 bc	1.0 c
4	Rimsulfuron	4 oz/A	0.9 bcd	1.7 cd	1.9 bc	1.7 c
5	Oxyfluorfen	3 pt/A	1.6 ab	2.1 cd	1.8 bc	1.1 c
6	Indaziflam	6.5 oz/A	0.7 cd	1.6 cd	1.8 bc	1.6 c
7	Pendimethalin	6.3 qt/A	0.9 cd	1.7 cd	2.4 b	1.6 c
8	Isoxaben	1.33 lb/A	0.5 d	1.2 d	1.3 bc	1.1 c
9	Saflufenacil	1 oz/A	1.4 bc	2.1 cd	1.8 bc	1.8 c
10	Clethodim	16 oz/A	0.9 bcd	1.4 cd	1.5 bc	1.5 c
11	Caprylic Acid	9%	1.2 bcd	2.3 c	2.2 bc	1.9 c
12	Glufosinate	56 oz/A	2.2 a	6.1 a	6.6 a	5.1 b
13	Glyphosate	3.8 lbs a.i./A, 7%	1.6 ab	4.6 b	7.1 a	8.3 a
14	Untreated		0.8 cd	1.4 cd	1.1 c	1.0 c
P-value			<0.0001	<0.0001	<0.0001	<0.0001

Means within a column followed by the same letter are not significantly different at the Fisher's LSD test at 0.05 level.

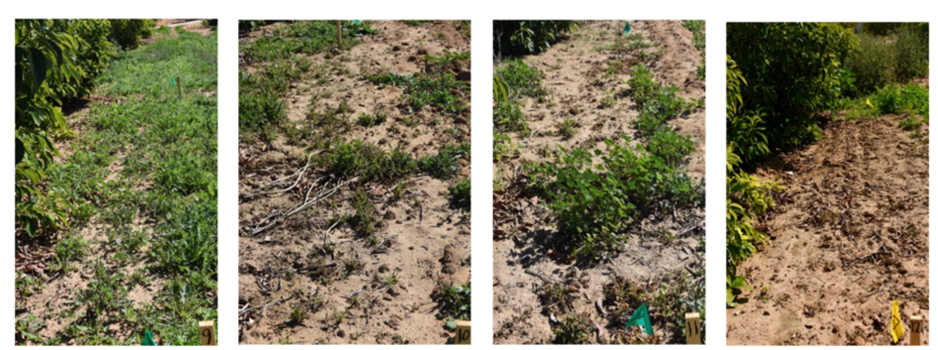
Figure 1. Avocado weed plots one week after treatment (WAT) at UCR.



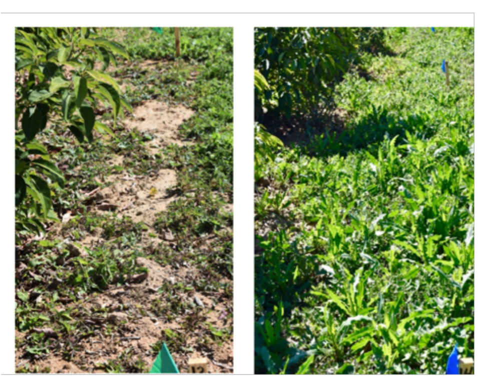
S-metolachlor 2 pt/A   Flumioxazin 12 oz/A   Simazine 4 lb/A   Rimsulfuron 4 oz/A



Oxyfluorfen 3 pt/A   Indaziflam 6.5 oz/A   Pendimethalin 6.3 qt/A   Isoxaben 1.33 lb/A



Saflufenacil 1 oz/A   Clethodim 16 oz/A   Caprylic Acid 9%   Glufosinate 56 oz/A

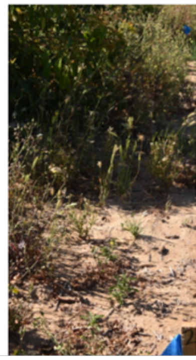


Glyphosate 3.8 lbs a.i./A   Untreated

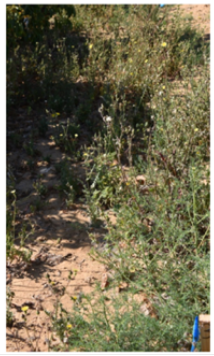
Figure 2. Avocado phytotoxicity plots one week after treatment (WAT) at UCR.

Figure 3. Avocado weed plots eight weeks after treatment (WAT) at UCR.

S-metolachlor 2 pt/A



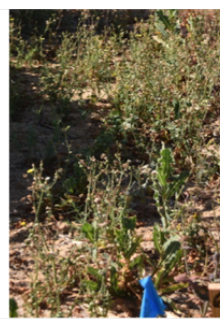
Flumioxazin 12 oz/A



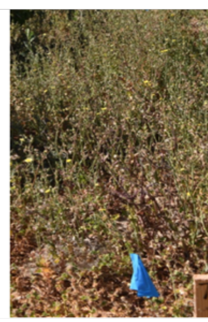
Simazine 4 lb/A

Rimsulfuron 4 oz/A

Oxyfluorfen 3 pt/A



Indaziflam 6.5 oz/A

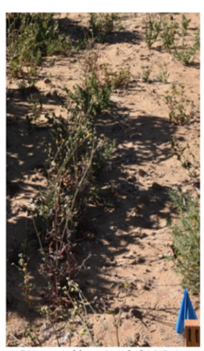


Pendimethalin 6.3 qt/A

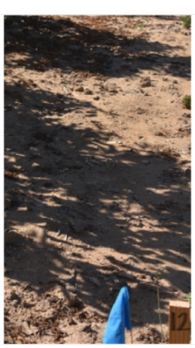
Isoxaben 1.33 lb/A

Saflufenacil 1 oz/A

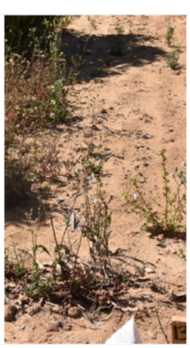
Clethodim 16 oz/A



Caprylic Acid 9%



Glufosinate 56 oz/A

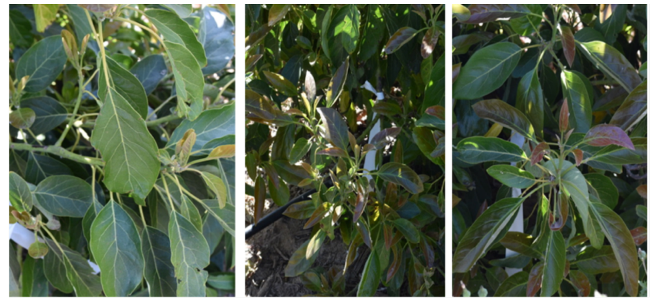


Glyphosate 3.8 lbs a.i./A

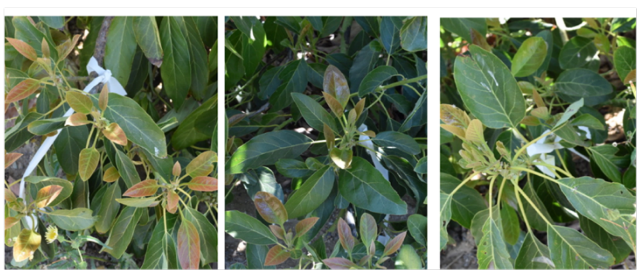
Untreated

Figure 4. Avocado phytotoxicity plots eight weeks after treatment (WAT) at UCR.

S-metolachlor 2 pt/A Flumioxazin 12 oz/A Simazine 4 lb/A



Pendimethalin 6.3 qt/A Isoxaben 1.33 lb/A Saflufenacil 1 oz/A



Rimsulfuron 4 oz/A Oxyfluorfen 3 pt/A Indaziflam 6.5 oz/A

Clethodim 16 oz/A Caprylic Acid 9% Glufosinate 56 oz/A

Glyphosate 3.8 lbs a.i./A Untreated

2022 Field trials:

Results of field trials, at UCR and HAREC, we found that glufosinate, glyphosate, saflufenacil caused little to no phytotoxic symptoms (Table 8A and B) whereas the combination of glufosinate+saflufenacil caused significantly more phytotoxicity (3.0-3.4). Phytotoxicity ratings at UCR tended to be higher than at HAREC. We attributed these differences to the use of surfactants at UCR site.

Although there was more phytotoxicity with glufosinate+saflufenacil, buds were undamaged and thus plants grew out of the damage. Based on these results, we proceeded with requesting registration of saflufenacil, however, due to issues in South America, BASF declined to pursue registration.

Table 8. Summary of phytotoxicity ratings for avocado for (A) UCR-Riverside field site and (B) HAREC-(Santa Paula) field site. Rating scale 1-10 (completely necrotic).

A. UC Riverside

Treatment	Day 7	Day 14	Day 28
Untreated	1.00^{c}	1.25^{b}	1.31
Glufosinate	2.25^{ab}	2.75^{ab}	2.50
Glufosinate+suflufenacil	3.25^{a}	3.00^{a}	2.81
Glyphosate	2.00^{bc}	1.81^{ab}	2.19
suflufenacil	2.75^{ab}	2.75^{ab}	2.81
F value	10.15	3.61	2.80
P>F	0.0004	0.0299	0.0644

B. HAREC

Treatment	Day 7	Day 14	Day 21	Day 28
Untreated	1.00^{b}	1.00^{b}	1.00^{b}	1.00^{b}
Glufosinate	1.31^{b}	1.75^{b}	1.08^{b}	1.42^{ab}
Glufosinate+suflufenacil	3.13^{a}	3.42^{a}	2.42^{a}	2.58^{a}
Glyphosate	1.00^{b}	1.00^{b}	1.75^{ab}	1.83^{ab}
suflufenacil	1.00^{b}	1.08^{b}	1.08^{b}	1.17^{b}
F value	8.41	10.69	5.75	4.53
P>F	0.0009	0.0003	0.0052	0.0134

Figure 1. Symptoms of phytotoxicity for each treatment 14 days after treatment (DAT): (A) Glyphosate, (B) Glufosinate, (C) Glufosinate + Suflufenacil, (D) Suflufenacil (E) Untreated.

Figure 2. Efficacy of Glufosinate+Suflufenacil 14 day after treatment to Russian thistle.

Conclusion:

As an industry, we need to shift our weed control focus to be proactive rather than reactive. We need to apply pre-emergent and early post-emergent PPO herbicides rather than react to established weeds. Glyphosate and/or glufosinate are important tools to treat weeds but should be used in addition to the other tools.

This research resulted in rimsulfuron (Matrix pre-emergent grass and broadleaf) and clethodim (post-emergent grass herbicide) receiving prioritization for registration through IR4 (federal program to support pesticide registrations in minor crops). These additional tools will be give growers an advantage in overall weed control. The first residue trials for rimsulfuron and clethodim were conducted in 2023. Earlier research by this team resulted in glufosinate being pushed forward for registration through IR4. Glufosinate is progressing toward receiving federal registration. Based on this work and the outreach that was conducted, other registrants have expressed interest in having trials continue and these will be conducted at UCR.

Publications/Outreach:

2020:

- Two blogs on weed control were published on UC Topics in Subtropics
- CAC/CAS/UC webinar devoted to avocado weed control

2021:

- Poster presentation, International Weed Science Society of America Conference.
- Poster presentation, National Association of County Agriculture Agents Conference (NACAA) where it also won best poster at the state and regional level and was one of four national finalists at the NACAA conference poster competition.

- Daugovish, O, B. Faber, D.Vega, G. Ferrari, V.Riffle, S. Rios, T. Bean and P. Mauk. 2021. Weed control and safety of herbicides in bearing avocado orchard. CAPCA Adviser 24(6): 60-64.

2022:

- Poster presentation, California Weed Science Society
- Oral presentation, California Association of Pest Control Advisers Annual Meeting in Anaheim

2023:

- Poster presentation, Avocado Brainstorming in Australia
- Oral presentation, Avocado Brainstorming in Australia (climate change session)
- Poster presentation, World Avocado Congress in Auckland, New Zealand