Research Trial Report:

Safety and Efficacy of Herbicides in Bearing Avocados

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In 2019, the California Avocado Commission funded a research project led by Dr. Travis Bean at the University of California Riverside to conduct efficacy trials on herbicides for use in bearing avocado groves. Tragically, less than a year into the project, Dr. Bean passed away unexpectedly. Dr. Peggy Mauk agreed to take over the project and see it through to completion and has recently submitted the final project report, which is summarized here.

Currently, only 10 herbicide active ingredients are registered for use on bearing avocados in California. Of these, paraquat is a restricted use chemical with high human toxicity that most growers prefer not to use. Also, glyphosate's (Roundup®) registration is under increasing scrutiny and many weeds are developing some level of resistance to it. Thus, trials were conducted with products containing active ingredients that are currently registered for use on citrus in California, to evaluate their efficacy and potential for phytotoxicity to avocados.

To account for differences in soil type and climate, research trials were established in two distinct growing regions (Ventura and Riverside Counties). Herbicides were applied in spring and fall to test efficacy in controlling different seasonal weed populations and to evaluate phytotoxicity during different seasonal phenological stages in avocado groves. Special attention was paid to immediate and cumulative phytotoxic effects. The study was repeated in two consecutive years at each site to address inter-year variations in weather and other factors, especially rainfall. Special consideration was 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. The major weed species present at both sites were tumble pigweed, common purslane, sow thistle, cheeseweed/mallow, stinging nettle and hairy fleabane.

Both pre- and post-emergence herbicides were selected for the trials. Products currently labeled for use on citrus in California have the advantage of being registered for use on another subtropical crop in the state and have known weed control spectra. The active ingredients selected for testing were: indaziflam (Alion®), pendimethalin (Prowl H2O®), rimsulfuron (Matrix®), S-metolachlor (Pennant Magnum®), saflufenacil (TreeVix®), isoxaben (Gallery®) and glufosinate-ammonium (Forfeit®). All these products were compared to currently registered active ingredients, which include oxyfluorfen (Goal®), flumioxazin (Chateau®), simazine (Princep®), glyphosate (Roundup®), prodiamine (Proclipse®), carfentrazone-ethyl (Shark®) and caprylic

Table 1. Rates and application timing for herbicides tested in avocado groves in Santa Paula and Riverside in 2019-2021.				
Treatment #	Pre/Post emergent	Product	Active Ingredient	Rate
1	Untreated Control			
2	Post	Forfeit 280	Glufosinate	56 oz/acre
3	Post	Roundup	Glyphosate	3.8 lbs a.i./acre, 7%
4	Post	Suppress	Caprylic Acid	9%
5	Post	Shadow 3EC	Clethodim	16 oz/acre
6	Pre/Post	Treevix	Saflufenacil	1 oz/acre
7	Pre/Post	Chateau EZ	Flumioxazin	12 oz/acre
8	Pre/Post	Goaltender	Oxyfluorfen	3 pt/acre
9	Pre	Alion	Indaziflam	6.5 oz/acre
10	Pre	Matrix SB	Rimsulfuron	4 oz/acre
11	Pre	Princep 4L	Simazine	4.4 lb/acre
12	Pre	Pennant Magnum	S-metolachlor	2 pt/acre
13	Pre	Prowl H2O	Pendimethalin	6.3 qt/acre
14	Pre	Gallery	Isoxaben	1.33 lb/acre

acid (Suppress®). Table 1 lists all the products, their type of activity (pre- or post-emergence) and the rates tested.

In Ventura County, the test site was at the UC Hansen Research and Extension Center (HREC) in Santa Paula on a 15-year-old Hass block. In Riverside County, the test site was at the Agricultural Experiment Station on the UC Riverside campus in a 2-year-old Hass block. A total of four applications were made at each site, two spring and two fall applications, and data was collected for eight to 10 weeks after treatment to evaluate weed suppression and phytotoxicity symptoms. Applications were made to test plots of approximately 40 to 60 square feet on the grove floor adjacent to the tree skirts to evaluate efficacy under typical grove conditions and to evaluate potential phytotoxicity from uptake by shallow avocado roots. Additionally, tree foliage was sprayed directly to simulate spray drift and determine direct phytotoxic effects. All applications were made using a backpack sprayer. Following treatment applications, herbicides were incorporated with simulated rainfall using a portable sprinkler to apply ½-inch of water. At all applications, weeds were 2-4 inches tall when treated. Treatments were made in October and November 2019, February and May 2020, November and December 2020, and March and April 2021.

In 2022, with the goal of submitting some herbicides for registration, an additional trial was conducted to further test the efficacy of the best performing herbicides from the previous trials and to test common tank mixes used in citrus. The trials were conducted at the HREC in Ventura County and at UCR in Riverside County using 19-year-old and 4-year-old trees, respectively. These treatments were made in June 2022, to test plots that were 20 feet long by 3.3 feet wide, parallel to the tree row and adjacent to the tree skirts. The herbicide rates and tank mixes used for the 2022 trials are shown in Table 2.

Table 2. Rates and tank mixtures used for the 2022 herbicide tests on avocado groves in Santa Paula and Riverside.			
Treatment #	Treatment	Rate	Surfactant*
1	Untreated Control		
2	Saflufenacil	1 oz/acre	5.2 lb/acre ammonium sulfate (AMS) and 1% methalated seed oil (MSO)
3	Glufosinate	56 oz/acre	5.2 lb/acre AMS and 1% MSO
4	Glufosinate + Saflufenacil	56 oz/acre + 1 oz/acre	5.2 lb/acre AMS and 1% MSO
5	Glyphosate	3.8 lb a.i./acre, 7%	5.2 lb/acre AMS and 1% MSO
*Surfactants were used in the test plots in Riverside but not in Santa Paula.			

Results

For the first set of trials there was a significant interaction between season and treatments at the UCR location, thus data are presented for spring and fall treatments separately. However, at the HREC location there was no interaction so data were pooled across seasons. An example of some of these data are shown in Tables 3 and 4.

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

Treatment	Rate	Percent Control			
		1 WAT	2 WAT	4 WAT	8 WAT
S-metolachlor	2 pt/A	1.3 e*	18.8 def	43.8 de	57.8 bcde
Flumioxazin	12 oz/A	7.0 cde	12.5 ef	26.3 ef	54.8 bcde
Simazine	4 lb/A	11.3 bcd	25.0 de	52.5 cde	76.8 abc
Rimsulfuron	4 oz/A	72.0 a	83.5 ab	92.3 a	75.0 abcd
Oxyfluorfen	3 pt/A	11.3 cde	31.3 de	38.8 def	52.5 cde
Indaziflam	6.5 oz/A	80.8 a	89.5 a	77.5 abc	68.3 bcd
Pendimethalin	6.3 qt/A	31.3 b	40.0 cd	48.3 cde	42.5 def
Isoxaben	1.33 lb/A	15.0 bcd	40.0 cd	44.5 de	56.3 bcde
Saflufenacil	1 oz/A	23.0 b	33.0 d	60.0 bcd	67.5 bcd
Clethodim	16 oz/A	3.3 de	6.3 fg	8.8 fg	16.3 fg
Caprylic Acid	9%	19.5 bc	28.3 de	32.5 def	26.3 ef
Glufosinate	56 oz/A	30.0 b	61.3 bc	79.3 ab	97.3 a
Glyphosate	3.8 lbs a.i./A, 7%	57.5 a	71.3 ab	81.3 ab	84.3 ab
Untreated		0.0 e	0.0 g	0.0 g	0.0 g
	P-value	<0.0001	<0.0001	<0.0001	<0.0001

*Means within a column followed by the same letter are not significantly different.

During spring and fall at the UCR location, glyphosate and glufosinate provided the best weed control through eight weeks after treatment. Saflufenacil, simazine, and indaziflam were the next best performing products in the fall. Phytotoxicity from glyphosate and glufosinate was observed for the entire eight weeks of observation. However, with glufosinate, the damaged buds remained viable and eventually produced new growth.

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.

Treatment	Rate	Phytotoxicity Rating*			
		1 WAT	2 WAT	4 WAT	8 WAT
S-metolachlor	2 pt/A	0.0 c**	0.0 d	0.0 d	1.3 bc
Flumioxazin	12 oz/A	0.0 c	0.0 d	0.1 d	0.0 c
Simazine	4 lb/A	0.0 c	0.0 d	0.0 d	1.3 bc
Rimsulfuron	4 oz/A	0.0 c	0.1 d	0.1 d	0.0 c
Oxyfluorfen	3 pt/A	0.0 c	0.0 d	0.0 d	0.1 c
Indaziflam	6.5 oz/A	0.7 bc	1.0 cd	1.0 cd	1.0 bc
Pendimethalin	6.3 qt/A	0.1 c	1.8 abc	0.0 d	0.1 c
Isoxaben	1.33 lb/A	0.4 bc	1.6 bc	1.7 bc	0.8 bc
Saflufenacil	1 oz/A	1.0 b	2.3 ab	2.5 ab	2.3 ab
Clethodim	16 oz/A	0.0 c	0.0 d	0.0 d	0.1 c
Caprylic Acid	9%	0.0 c	0.8 cd	2.1 abc	1.1 bc
Glufosinate	56 oz/A	1.1 b	2.5 ab	3.3 a	3.1 a
Glyphosate	3.8 lbs a.i./A, 7%	2.8 a	3.0 a	3.0 ab	4.0 a
Untreated		0.0 c	0.0 d	0.0 d	0.0 c
	P-value	<0.0001	<0.0001	<0.0001	<0.0001

*Phytotoxicity was visually rated on a scale of 0 (no phytotoxicity) to 10 (dead tissue).

**Means within a column followed by the same letter are not significantly different at the 0.05 level.

At the HREC location, glyphosate and glufosinate also provided the best weed control through eight weeks after treatment. Phytotoxicity and regrowth was observed at HREC similar to what was observed at UCR.

A consistent result that was observed at both locations was that protoporphyrinogen oxidase (PPO) inhibitor herbicides, such as oxyflourofen and flumioxazin, provided good control of germinating and recently germinated weeds, but were not effective on established weeds. Thus, these products would not be good as stand-alone herbicides, but may have a role as a component in an integrated weed control program.

Results from the 2022 trials showed little to no phytotoxicity from glyphosate, glufosinate or saflufenacil alone, but the combination of glufosinate+saflufenacil caused significantly more phytotoxicity. Although the phytotoxicity ratings were higher with the combination treatment, buds were not killed, and the trees eventually grew out of the damage.

Conclusions

Based on the results of these trials, a request was made for registration of saflufenacil. However, because of issues with phytotoxicity observed on avocados in South America, BASF, the registrant for saflufenacil, declined to support a registration.

The products rimsulfuron (Matrix® a pre-emergence grass and broadleaf herbicide) and clethodim (Shadow® a post-emergence grass herbicide) were both supported for registration by their respective registrants and have entered the IR-4 program. The first residue trials for both these products were conducted in 2023 at UCR and the products are moving through the registration process.

Glufosinate was already in the IR-4 program when this research was conducted and a registration for avocados was anticipated. Recently a Section 24C Special Local Needs registration for the use of glufosinate on avocados was issued; however, *California is NOT INCLUDED in this registration.* CAC is working with the California Department of Pesticide Registration to understand this exclusion and to determine what can be done to make this tool available for California avocado growers.

Dr. Mauk stresses that 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 [oxyfluorfen (Goal®) and flumioxazin (Chateau®)] rather than react to established weeds. Glyphosate and/or glufosinate (when it becomes available) are important tools to treat weeds but should be used in addition to the other tools we have available.