Title
Characterization of the Preemergence Herbicide Pyroxasulfone for Use in California Orchard Systems

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Characterization of the Preemergence Herbicide Pyroxasulfone

for Use in California Orchard Systems

By

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Abstract

Identification of potential weed management tools for California tree nut orchard systems is an ongoing endeavor. Proper weed management reduces competition with the crop and facilitates harvest. Many weed control programs include the use of preemergence and postemergence herbicides. However, selection pressure has led to herbicide-resistant weeds which require additional options. A potential tool for orchard weed management is pyroxasulfone, an HRAC/WSSA group 15 herbicide that is an inhibitor of very long-chain fatty acid synthesis. Pyroxasulfone is registered as a preplant incorporated or preemergence herbicide, in corn, soybean, and cotton in some Midwestern states of the United States. However, there is limited published literature on the use of pyroxasulfone in tree nut orchard systems. A series of crop safety and weed control efficacy experiments were carried out for the characterization of pyroxasulfone in California orchard crops. A suspension concentrate (SC) formulation of pyroxasulfone was evaluated in fallow field studies initiated in fall 2020 and carried out into summer 2022 near Davis, CA. Studies were conducted to evaluate the weed control efficacy of pyroxasulfone at 145, 219, and 293 g ha^{-1} rates. In addition, an experiment was conducted in the summer of 2021 to evaluate herbicide efficacy in response to two incorporation timings. Single application and sequential applications experiments evaluated the use of a water dispersible granule (WDG) formulation of pyroxasulfone or pyroxasulfone (SC) at multiple rates in comparison to commercially used standards flumioxazin, indaziflam, oxyfluorfen, pendimethalin, penoxsulam + oxyfluorfen, and rimsulfuron. Experiments were conducted in a fallow field, a vineyard and in almond and walnut orchards near Arbuckle, Davis, and Winters, CA in spring 2021 and spring 2022. A two-year crop safety experiment was conducted to evaluate repeated applications of above-label rates including pyroxasulfone at 1,199 g ha^{-1} and S-metolachlor at 14,010 g ha^{-1} on 1-2-yrs-old tree nut crops in spring 2021 and spring 2022. Both formulations of pyroxasulfone SC and WDG performed similarly to commercial standards with up to 95% control of broadleaf and grass weeds. No significant differences in weed control were found among treatments in the incorporation timing study. Crop injury was not observed in the vineyard, established orchard, or young orchard studies and there were no treatment effects on tree trunk diameter of almond, pistachio, and walnut in the two-year crop safety study. These results indicate a potential for pyroxasulfone in California tree nut orchard systems which would be a new mode of action and benefit to manage herbicide-resistant weeds in these crops.

Key words: crop safety, pyroxasulfone, tree nut cops, and weed control.

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Introduction

Orchard crops contribute substantially to the California economy, with almonds (*Prunus dulcis*) alone bringing in 5.03 billion dollars; pistachios (*Pistacia vera*) and walnuts (*Juglans regia*) contribute 2.91 and 1.02 billion dollars, respectively (CDFA, 2021). There are various reasons to practice proper weed management in orchard crops, but two of the most important are to reduce competition with the crop and to facilitate harvest. Weeds have the ability to rapidly develop dense root systems and compete for nutrients and water which can limit young tree growth and fruit yield (Goff et al., 1991). Weeds also interfere with cultural practices, as is the case of almond and walnut harvest, in which the nuts are mechanically shaken from the tree, swept into windrows in the orchard alley, and are left to dry for seven to ten days before they are picked up for processing (Carbo and Connell, 2017). Weed debris can interfere with these practices making it slower and more difficult to recover the nuts.

Weed control programs in conventionally-managed orchards in California typically include tree strip applications of preemergence (PRE) herbicides in early winter followed by postemergence (POST) herbicides in spring, mowing of the alleyways during spring and summer, and a full orchard floor treatment with POST herbicides prior to harvest (Buchner et al., 1998; Connell et al., 1996; Hanson et al., 2017). The use of broad spectrum herbicides with the same mode of action consecutively has led to resistance in weed species such as annual bluegrass (*Poa annua*), barnyardgrass (*Echinochloa crus-galli*), hairy fleabane (*Erigeran bonariensis*), horseweed (*Erigeran canadensis*), Italian ryegrass (*Lolium multiflorum*), and junglerice (*Echinochloa colona*) all of which are commonly found in California orchards (Hanson et al., 2014; Heap, 2023). While PRE herbicides usage has risen in orchard and row cropping systems where resistance to multiple POST herbicides has developed reliance on the same mode of action

POST or PRE herbicides can eventually lead to weed species to develop resistance as a result of herbicide selection pressure (Gressel and Segel, 1978; Heap, 2023). In efforts to manage herbicide resistance, new herbicides are being developed or explored for uses in additional cropping systems.

In 2011 pyroxasulfone was introduced into the pesticide market (APVMA, 2011) and later it was registered for use in corn, soybean, and cotton in Midwestern states of the U.S. (Nakatani et al., 2016). Pyroxasulfone is an inhibitor of very long chain fatty acids (VLCFA), belonging to HRAC/WSSA group 15 herbicides (Nakatani et al., 2016; Tanetani et al., 2009, 2011). Resistance to VLCFA-inhibitors is limited so far with only thirteen weed species having demonstrated resistance (Kumar et al., 2015; Strom et al., 2019; Heap, 2023). Pyroxasulfone has had experimental uses in PRE and POST (typically early post) weed control programs, however results have demonstrated greater weed control efficacy with PRE applications as compared with other VLCFA-inhibitors (Stephenson et al., 2017; Lee, 2018; McNaughton et al., 2014).

VLCFA-inhibitors are most effective in the cotyledon stage of susceptible plants, they inhibit early developments of VLCFA in roots and shoots (Böger et al., 2000, 2003; Tanetani et al., 2011). VLCFA are fatty acid carbon chains that are composed of more than 18 carbon atoms. VLCFA-inhibitors have been found to halt the elongation of C18:0, C20:0, C22:0, C24:0, C26:0, and C28:0 as well as the reduction of C18:1, C20:1, and C22:1 VLCFAs (Böger et al., 2000, 2003; Tanetani et al., 2011). VLCFA-inhibitors function by inhibiting the VLCFAs synthesizing enzyme VLCFA elongase (VLCFA-E). The presumed target site of VLCFA-E is the thiol bond found on the amino acid cysteine (Böger et al., 2000, 2003; Eckermann et al., 2003).

Pyroxasulfone has physicochemical properties that make it a viable tool to use in weed control programs. It has a low affinity for organic matter with a K_{oc} of 51-114, and a low water solubility of 3.94 mg L^{-1} (Table 1) (Tanetani et al., 2009; Nakatani et al., 2016; Ney, 1995). Odero and Wright (2013) found that pyroxasulfone at rates of 194-271 g ha^{-1} (g ha^{-1}) can provide up to 90% weed control on soils with 80% organic matter (OM). However, Yamaji et al. (2016) found that soils with up to 3% OM can overcome pyroxasulfone's K_{oc} and suggested a pyroxasulfone rate of 200-300 g ha^{-1}. Yamaji et al. (2016) hypothesized that OM does not necessarily influence pyroxasulfone's efficacy. Due to its low water solubility and presumably low affinity for organic matter, concerns for crop damage and leaching arose in regard to pyroxasulfone mobility in soil. Westra et al. (2014) evaluated pyroxasulfone at 280 g ha^{-1} on clay loam and sandy loam soil and found that mobility was greater in the sandy loam and that additional water by irrigation or rainfall can cause up to 14.6% of pyroxasulfone to leach into the 150-225 mm depth of the soil profile.

Previous experiments have evaluated the crop safety and weed control efficacy of pyroxasulfone compared to atrazine, S-metolachlor, and other commonly used PRE herbicides in cotton, corn, field pea, rice, soybean, and wheat production systems (Belfry et al., 2015; Geier et al., 2006, 2009; Godwin et al., 2018; King et al., 2007, 2008; Kleemann et al., 2016; Stephenson et al., 2017; Tidemann et al., 2014; Walsh et al., 2011; Webb, 2015). Given the demonstrated weed control spectrum and broad use in many annual crops, pyroxasulfone could also be useful in orchard crops. Additionally, as a group 15 herbicide pryoxasulfone would provide an alternative mode of action for herbicide-resistant weeds in orchards. Currently napropamide is the only VLFCA-inhibitor registered for use in California vineyards and almond orchards although it is not widely used (CDPR, 2023). Few pyroxasulfone studies have been conducted in tree nut cropping systems; therefore, the objectives of this research were to evaluate the crop safety and weed control efficacy of pyroxasulfone in irrigated California tree nut orchard production systems.

Materials and Methods

Weed control experiments. The suspension concentrate (SC) and water dispersible granule (WDG) formulations of pyroxasulfone were evaluated for crop safety and control of broadleaf and grass weeds. A crop safety experiment and six weed control experiments were conducted where pyroxasulfone was compared to commercial preemergence standards flumioxazin, indaziflam, oxyfluorfen, pendimethalin, penoxsulam + oxyfluorfen, rimsulfuron, and S-metolachlor (Table 2). In all experiments, assessments were conducted in reference to nontreated control plots. Crop safety assessments were conducted every 7 days up to 30 days after treatment (DAT) and followed by assessments every 15 days between 30-120 DAT. Visual weed control assessments were conducted every 15 days up to 90 DAT and followed by assessments every 30 days 90-180 DAT.

Studies for fall and spring fallow field experiments were conducted at the Plant Sciences Field Facility of the University of California, Davis (UCD) (38.531614, -121.784142). Studies were conducted in fall 2020 (study 1), fall 2021 (study 2), spring 2021 (study 3), and spring 2022 (study 4) (Table 3).). In this region, most annual precipitation occurs during late fall to early spring; during these fall fallow field experiments, study 1 received 101.6 mm of rain and study 2 received 190.5 mm of rain during the first thirty days after treatment (CIMIS 2023).

Spring fallow field experiment studies were sprinkler irrigated due to complete lack of rainfall; study 3 received 50.8 mm of water 21 DAT, and study 4 received 12.7 mm of water weekly for 8 weeks. In study 2 a maintenance spray with glufosinate at 1,143 g ha^{-1} was conducted on January 12, 2022, at 30 DAT to control a heavy population of swinecress

(*Lepidium coronopus*). A sprayer problem occurred during the spray treatment application in study 4, which led to inconclusive results.

An irrigation incorporation experiment (study 5) was conducted at the Plant Sciences Field Facility of the UCD (38.531614, -121.785567) in summer 2021 to evaluate performance differences in herbicide applications made relative to two irrigation incorporation timings (Table 3). Each main plot was divided into two subplots; the subplots received the same herbicide treatment but at different application timings relative to the first sprinkler irrigation. Applications “A” and “B” were conducted 18 and 5 days before initial irrigation, respectively. Approximately 12.7 mm of water was applied weekly via sprinkler irrigation up to 120 DAT-B (days after treatment B). Due to an abundance of field bindweed (*Convolvulus arvensis*) a maintenance spray was conducted on July 3, 2021, (45 DAT-B) with glyphosate at 1,548 g a.e. ha^{-1}. Additional spot spraying with glyphosate at 8.78 g a.e. L^{-1} for control of field bindweed was conducted twice a month up until 120 DAT-B.

Sequential application experiment studies were conducted in a fallow field (study 6) at the Plant Pathology Field Facility of the UCD (38.522144, -121.765781) in spring 2021 and in a two-year-old almond orchard (study 7) at the Nickels Soil Lab of the University of California (UC) near Arbuckle, CA (38.956263, -122.070359) in spring 2022 (Table 4). Single application orchard experiment studies were conducted in a walnut orchard (study 8) at the Plant Sciences Field Facility of the UCD (38.542565, -121.794735), and a two-year-old almond orchard (study 9) at the Nickels Soil Lab of the UC near Arbuckle, CA (38.956263, -122.070359) in spring 2022. Orchard and vineyard experiment studies were conducted in an established almond orchard at the Plant Sciences Field Facility of the UCD (38.544808, -121.791746) (study 10), in an established almond orchard at the Wolfskill Experimental Orchards of the UCD (38.504184, -

121.978701) (study 11), and in a vineyard (study 12) at the Viticulture and Enology Tyree Vineyard of the UCD (38.525250, -121.788728). Study 6 was sprinkler irrigated with 51.1 mm of water 21 DAT-B to encourage weed growth. Studies 7, 9, and 12 were drip irrigated while studies 8, 10, and 11 were microsprinkler irrigated. Irrigation was based on crop need as determined by the local orchard or vineyard manager.

Crop safety experiment. A series of crop safety studies were conducted in a young (< 2-yrs-old) mixed species orchard which included almond (study 13), pistachio (study 14), and walnut (study 15) trees at the Plant Sciences Field Facility of the UCD (38.538413, -121.794495) (Table 5). The orchard was planted in March of 2020, studies were initiated in February of 2021 and continued for a second application the following year. Pyroxasulfone at 1,199 g ha^{-1} and S-metolachlor at 14,010 g ha^{-1} were evaluated for crop safety. Applications were made during spring either before (timing "A") or after (timing "B") blooming and leafing of trees. Visual tree injury assessments were conducted in reference to nontreated plots. Assessments were conducted every 7 days up to 45 DAT-A and -B, followed by assessments every 15 days between 30-120 DAT-B. Trunk diameter measurements were taken before studies initiation, one year after treatment (2022), and two years after the initial treatment (2023). The orchard was drip irrigated based on crop need as determined by the orchard manager.

Study application methods. A randomized complete block design (RCBD) was used for most studies, except study 5 which was conducted as split plot design (SPD). Treatments were applied using a compressed carbon dioxide backpack sprayer. For control of existing weeds, POST herbicide treatments were added to the mixes; various rates of glufosinate (984 – 1,704 g ha^{-1}) and glyphosate (1,548 – 3,083 g ha^{-1}) were applied in accordance with the size and density of weeds present.

Soil analyses: Soil samples from each field site were collected and oven dried at 40°C. The soil samples were sieved with a 2 mm mesh screen and 500 g subsamples were sent to the UCD Analytic Lab for characterization.

Statistical analysis. All data were analyzed using a one-way analysis of variance and means separated using Fisher's Protected LSD test with a confidence interval of 0.05, where applicable. For study 5, data were first analyzed as an SPD; however, statistical calculations demonstrated no significant differences between the two incorporation timings. Therefore, the weed control data within each plot were averaged over both incorporation timings and reanalyzed as a RCBD with a factorial arrangement of herbicide treatments (N = 8). The model used for analysis of tree trunk diameter in the crop safety experiments was a linear regression model.

$$Y = A + B(X)$$

Where "Y" is the trunk diameter measurement, "A" is the y intercept, "B' is the slope of the line, and "X" is year of measurement (Bevans 2022). All analyses were conducted using R version 4.2.2. (Posit Team 2022).

Results and Discussion

Fall fallow field experiment. In study 1, during the first 30 DAT overall weed control averaged 89% (Table 6). By 75 DAT overall control ranged from pendimethalin at 4,259 g ha^{-1} with 63% to indaziflam at 73 g ha^{-1} with 92%. Overall weed control provided by pyroxasulfone ranged from 65 to 85%. The average control for the dominant weed species filaree (*Erodium* spp.) and shepherd's purse (*Capsella bursa-pastoris*) were 71 and 72%, respectively.

In study 2, 190.5 mm of rainfall were received during the first 10 DAT leading to an abundance of swinecress growth during the first 30 DAT (Table 6). At 30 DAT, indaziflam at

52 and 73 g ha^{-1} provided the best overall control with 70 and 76%, respectively, and the best control of swinecress with 76 and 93% control, respectively. A maintenance treatment was applied after the 30 DAT evaluation. At 75 DAT swinecress had begun to regrow with an average control of 84% and no differences among treatments.

Spring fallow field experiment. In study 3, overall weed control at 30 DAT averaged 92% (Table 7). The two most dominant weeds in the study were redroot pigweed (*Amaranthus retroflexus*) and common lambsquarters (*Chenopodium album*). At 30 DAT pyroxasulfone provided 75-88% control of redroot pigweed while indaziflam and pendimethalin treatments provided less than 63% control, although there were no statistical differences among treatments. The average control for common lambsquarters was 71%; pyroxasulfone provided 50-100% control. By 60 DAT overall control declined to an average of 54%. No treatment provided control of redroot pigweed with an average control of 13%. Pyroxasulfone at 293 g ha^{-1} provided the highest control of common lambsquarters with 88%.

Our results agree with an experiment conducted by Nurse et al. (2011) where < 80% control of common lambsquarters was provided with rates of pyroxasulfone lower than 250 g ha^{-1}. For redroot pigweed Nurse et al. (2011) observed that pyroxasulfone at 93 g ha^{-1} provided 90% control at 56 DAT; in contrast to our results where pyroxasulfone at 134 and 268 g ha^{-1} provided 0-13% control of redroot pigweed at 60 DAT. Pyroxasulfone has been evaluated for control of other pigweed species. Meyer et al. (2016) observed pyroxasulfone at 179 g ha^{-1} provided 98% control of common waterhemp (*Amaranthus tuberculatus*) at 21 DAT and provided 96% control of Palmer amaranth (*Amaranthus palmeri*) at 30 DAT. Results from Houston et al. (2019) demonstrated that pyroxasulfone at 368 g ha^{-1} provided up to 79% control of Palmer amaranth at 35 DAT. Our results agree with Meyer et al. (2016) and Houston et al. (2019) that during the first 30 DAT pyroxasulfone can suppress pigweed species.

Differences in control among pyroxasulfone, pendimethalin, and indaziflam may be caused by chemical and physiochemical proprieties. All three compounds have a relatively low water solubility (< 10 mg L^{-1}) but there are differences in organic binding (Table 1). A low organic binding affinity can increase soil mobility and when combined with a low water solubility both can lead to a decrease in residual activity. In study 1, indaziflam demonstrated the greatest control at later evaluation dates indicating longer residual activity. Pyroxasulfone and pendimethalin provided similar results to each other in study 1 and 2 despite differences in physiochemical properties. However, study 3 demonstrated that weed species can be affected differently despite differences in physiochemical properties of the herbicides. Instead, differences are likely a result of a herbicide's mode of action or a weed's herbicide susceptibility.

Irrigation incorporation experiment. In study 5, the weed control efficacy of pyroxasulfone, pendimethalin, and indaziflam were measured as a stability response to two incorporation timings. Overall weed control 90 DAT-B averaged 93% and decreased to 88% by 150 DAT-B (Table 8). The most widespread weed in this location was yellow nutsedge (*Cyperus esculentus*). Pyroxasulfone at 219 and 293 g ha^{-1} provided 73% control of yellow nutsedge while all other treatments provided less than 65% control. The irrigation incorporation study demonstrated no differences in the tested PRE herbicide residual activity when incorporated 5 or 18 days after treatment application. The California Central Valley typically receives rain during the winter November-March. Without rainfall irrigation incorporation may be required (Jordan et al., 1963; Knake et al., 1967; Smith et al., 2016). The longer a PRE herbicide is left on the soil surface without incorporation the higher the probability of dissipation, especially during the summer months when temperatures can reach up to 38°C (Savage and Barrentine, 1969). Our study did not directly evaluate dissipation of any treatment; however, adequate residual control was observed throughout its entirety when the average air temperature was 33°C regardless of whether it was sprinkler incorporated 5 or 18 days after treatment

Previous experiments have been conducted to evaluate the dissipation of pyroxasulfone. Mueller and Steckel (2011) evaluated pyroxasulfone at 1,500 g ha^{-1} on loam soils with 1.9% OM, with 7-17 mm of rainfall incorporation and with 160-443 mm of total water (rainfall + irrigation) for the experiment; their results suggested a half-life of 8-71 days. Westra et al. (2014) evaluated pyroxasulfone at 280 g ha^{-1} on fine clay and sandy loam soils with 1.1-1.5% OM, with 13 mm irrigation incorporation and 288-731 mm of total water for the study with results suggesting a half-life of 104-134 days. In each experiment, the lower half-life corresponded with the highest amount of water received. However, Yamaji et al. (2016) found that pyroxasulfone at 125 g ha^{-1} tested on all soil types has a >88% overall weed control efficacy when there is more than 12.5 mm of water incorporation during the first 7 DAT. Treatments in study 5 maintained ≥ 88% overall weed control despite having more than 7 days before incorporation with 12.7 mm of water, and 203.2 mm of total irrigation on loam soil with 1.5% OM. This suggests that there may be a range for how much water can be present before in an increase in dissipation occurs. A follow up experiment evaluating dissipation response to an increase in water should be conducted.

Sequential application experiment. Study 6 was conducted on fallow field, at 60 DAT-B overall weed control averaged 86% (Table 9). Multiple weeds species were observed in control plots but had limited weed pressure with less than 10% ground cover, likely caused by limited water presence. Treatments provided adequate weed control of all weeds except for field bindweed with an average control of 23%.

Study 7 was conducted in an almond orchard with drip irrigation; herbicide injury was not documented on any trees (data not shown). At 60 DAT-B the overall control averaged 89% (Table 9) similar to study 6. By 90 DAT-B overall weed control decreased to 70%. This was largely due to field bindweed which was only controlled 0-33%.

The sequential application experiment evaluated pyroxasulfone when used in such programs. Many sequential application programs include the use of two application timings with different mode of action herbicides to increase weed control efficacy and decrease herbicide resistance. Brunharo et al. (2020) evaluated sequential application treatments versus single application treatments in almond orchards. They found that sequential treatments increased weed control during the growing season. This supports results from studies 7 and 8 which had limited weed growth with an average overall weed control ≥ 86% at 60 DAT-B despite the different irrigation regimens.

Single application orchard experiment. Study 8 was conducted in an almond orchard, by 60 DAT overall weed control averaged 89% (Table 10). There was limited control of field bindweed with all treatments providing 0-67% control but due to high spatial variability there were no differences among treatments.

Study 9 was conducted in a walnut orchard and, across treatments, had an average of 86% overall control during the first 30 DAT (Table 10). The average control for the dominant weed bermudagrass (*Cynodon dactylon*) was 71%. Pyroxasulfone at 219 and 293 g ha^{-1} provided 60 and 48% control of bermudagrass, respectively. By 60 DAT the average overall control was 67% as a result of the limited suppression of bermudagrass and foxtail barley (*Hordeum* *jubatum*). The average control for bermudagrass and foxtail barley was 28 and 64%, respectively. Pendimethalin at 4,259 and 6,389 g ha^{-1} provided 93 and 96% control of foxtail barley, respectively, while all other treatments provided < 77% control, although there were no statistical differences among treatments.

The single application orchard experiment had an additional evaluation on different rates of indaziflam and glufosinate. Many PRE herbicides have limited effects on emerged plants, requiring appropriate burndown treatments to control existing weeds. This experiment evaluated the residual efficacy of pendimethalin and pyroxasulfone each mixed with a standard rate (1,334 g ha^{-1}) of glufosinate in comparison to indaziflam when mixed with various rates of glufosinate. The different rates of glufosinate provided no differences in burndown control of existing weeds in both studies (data not shown). However, incomplete burndown in study 9 led to regrowth of foxtail barley.

Orchard and vineyard experiment. Studies 10-12: During the spring of 2021 rainfall was limited to 114 mm which likely limited weed pressure. The overall weed control averages for studies 10 (almond orchard), 11 (almond orchard), and 12 (vineyard) by 120 DAT were 91, 91, and 98%, respectively (Table 11). Pyroxasulfone at 150, 225, and 300 g ha^{-1} provided an average overall weed control of 95, 95, and 93%, respectively, across all three studies. Herbicide injury was not observed on any trees or vines (data not shown).

The orchard and vineyard experiments were a single application protocol evaluating the WDG formulation of pyroxasulfone against other PRE herbicides including tank mixes and premixed formulations. One of the premixed formulations was flumioxazin + pyroxasulfone. Flumioxazin is a cell membrane disruptor that inhibits the enzyme protoporphyrinogen oxidase (PPO), leading to the disintegration of a cells plasmalemma (plasma membrane) (EPA, 2003;

Price et al., 2004). The co-application of flumioxazin plus pyroxasulfone has been found to increase control of multiple herbicide-resistant common waterhemp (Ferrier et al., 2022). Ferrier et al. (2022) observed a longer residual control of common waterhemp with flumioxazin + pyroxasulfone (134 + 106 g ha^{-1}) with up to 95% control vs solo pyroxasulfone (134 g ha^{-1}) with 78%, or solo flumioxazin (106 g ha^{-1}) with 73% at 84 DAT. Follow up studies should be conducted to evaluate both formulations of pyroxasulfone as well as the premix of flumioxazin + pyroxasulfone.

Crop safety studies. After treatments in the spring the first and second years after transplanting, all treated almond, pistachio, and walnut trees blossomed and leafed out similarly to the untreated trees in the subsequent season (data not shown). Growth was not affected by herbicide treatments of pyroxasulfone at 1,199 g ha^{-1} and S-metolachlor at 14,010 g ha^{-1} (Figures 1, 2, and 3). Almond and walnut trees had an approximately 40- and 25-mm increase in diameter each season, respectively (Figures 1 and 2). Pistachios had an increase of approximately 30-mm at the end of the study (Figure 3); however, these results were affected by significant ground squirrel damage in the young pistachio trees.

These crop safety results support an experiment by Pedroso and Moretti (2022) conducted on transplanted hazelnuts. Pedroso and Moretti (2022) found that pyroxasulfone at 240-950 g ha^{-1} and S-metolachlor at 1,390-4,160 g ha^{-1} provided no differences among treatments in trunk cross-sectional areas and with negligible (< 3%) node injury. Both crop safety experiments conducted on tree nuts crops did not document any significant injury by any pyroxasulfone or S-metolachlor treatment.

Overall conclusion. Pyroxasulfone SC and WDG have demonstrated potential to be used as a California orchard systems herbicide, with similar performance to commercially used herbicides. Treatment related injury was not documented on any of the established (≥ 4-yrs-old) or young trees (≤ 2-yrs-old) tested, even when used at an extremely high pyroxasulfone rate of 1,199 g ha^{-1}. In the fall fallow field experiment indaziflam provided the greatest weed control while pendimethalin and pyroxasulfone provided similar overall weed control results to each other. In the spring fallow field experiment, pyroxasulfone (293 gha^{-1}) was the only herbicide to suppress (> 70%) common lambsquarters at 60 DAT, this indicates possible differences in weed species susceptibility to the different chemistries tested. However, in the irrigation incorporation experiment all three-herbicides provided similar weed control. These results indicate that despite chemical and mode of action differences proper incorporation ensures optimal herbicide performance.

Future experiments should evaluate different incorporation methods including drip irrigation versus sprinkler irrigation and how this can affect PRE herbicide weed control performance and soil dissipation. An analytical component should be used to evaluate herbicide stability with the parent molecule and metabolites analyzed to properly determine dissipation rates under different soil type, organic matter content, and water status conditions common in California orchard production systems.

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Table 1. Physiochemical proprieties of three preemergence herbicides used in weed control experiments.

	K_{oc}	Water solubility at 20°C mg/L	Melting point °C
Pyroxasulfone[1]	51-114	3.94	138
Indaziflam[2]	396-789	2.8	184
Pendimethalin[3]	13,400-65,000	0.32	56

[1]Nakatani et al. 2016
[2]EPA 2010
[3]ARS 1995

Table 2. Source of herbicides used in characterization of pyroxasulfone in California orchard systems.

Active ingredient	Trade name	Formulation	Manufacturer	City
Flumioxazin	Chateau®	51 % wt	Valent U.S.A. LLC	San Ramon, CA
Flumioxazin + Pyroxasulfone	Fierce EZ®	14 % + 18 % wt	Valent U.S.A. LLC	San Ramon, CA
Glufosinate	Rely 280®	280 g a.i. L^{-1}	Bayer Crop Science LP	Research Triangle Park, NC
Glyphosate	Roundup Powermax®	659 g a.e. L^{-1}	Bayer Crop Science LP	Research Triangle Park, NC
Indaziflam	Alion®	200 g a.i. L^{-1}	Bayer Crop Science LP	Research Triangle Park, NC
Pendimethalin	Prowl H_2O®	455 g a.i. L^{-1}	BASF Corporation	Research Triangle Park, NC
Penoxsulam + Oxyfluorfen	Pindar GT®	10 + 471 g a.i. L^{-1}	Corteva Agriscience	Wilmington, DE
Pyroxasulfone (SC)	Exp-82[1]	500 g a.i. L^{-1}	BASF Corporation	Research Triangle Park, NC
Pyroxasulfone (WDG)	Exp-94[2]	85 % wt	BASF Corporation	Research Triangle Park, NC
Oxyfluorfen	Goal 2XL®	239.65 g a.i. L^{-1}	Nufarm	Alsip, IL
Rimsulfuron	Matrix®	25 % wt	Corteva Agriscience	Wilmington, DE
S-metolachlor	Dual II Magnum®	915 g a.i. L^{-1}	Syngenta Crop Protection, LLC	Greensboro, NC

[1]Exp-82 = experimental pyroxasulfone formulation under evaluation
[2]Exp-94 = experimental pyroxasulfone formulation under evaluation

Table 3. Application details with pyroxasulfone, indaziflam, and pendimethalin in fall and spring fallow field experiments and the irrigation incorporation experiment near Davis, CA.

	Fall 2020 Study 1	Fall 2021 Study 2	Spring 2021 Study 3	Spring 2022 Study 4	—— Summer 2021 —— ——— Study 5 ———	
Application	--				A[1]	B
Plot size	------------------------------1.52 x 6.1 m ----------------------------				---------2.44 x 9.14 m--------	
Date	December 12, 2020	December 6, 2021	March 25, 2021	March 24, 2022	May 28, 2021	June 10, 2021
Time	8:30am	12:48pm	10:00am	12:50pm	9:40am	4:30pm
Type of sprayer	--CO_2 backpack sprayer--					
Boom size	------------------------3 nozzles 508 mm spacing-------------------				-4 nozzles 508 mm spacing-	
Type of nozzles	AIXR11003	AIXR11003	AIXR110025	AIXR11003	AIXR11003	AIXR11003
Gallons per acre	30	25	25	30	25	25
Cloud cover	10	100	30	0	5%	2%
Air temperature	14.4°C	7.8°C	0	19.4°C	18.8°C	23.8°C
Relative humidity	31%	99%	70%	58%	56%	21%
Soil temperature at 2 in.	8.9°C	7.8°C	11.1°C	13.3°C	18.2°C	22.1°C
Wind speed kph	9.01	7.41	12.8	6.44	6.44	11.1
Wind direction	East	North	Northwest	North	North	North
Days before irrigation	--				18 days	5 days
Soil texture	--Loam---					
Soil organic matter	--1.5%---					
Soil pH	--6.79---					

[1]Application "A" was applied 18 days before initial irrigation. Application "B" was applied 5 days before initial irrigation.

Table 4. Application details for weed control experiments evaluating pyroxasulfone in comparison to other preemergence herbicides in a fallow field, vineyard, and almond and walnut orchards near Arbuckle, Davis, and Winters CA in spring 2021.

	Sequential application experiment				Single application orchard experiment		Orchard and vine experiment		
	Fallow field		Young almonds (2-yrs-old)		Young almonds (2-yrs-old)	Walnuts (8-yrs-old)	Established almonds (8-yrs-old)	Established almonds (4-yrs-old)	Vineyard (~25-yrs-old)
	Study 6		Study 7		Study 8	Study 9	Study 10	Study 11	Study 12
Tree variety	----------		Nonpareil		Nonpareil	Chandler	Aldrich and Nonpareil	Aldrich and Nonpareil	Grenache
Location	Davis	Davis	Arbuckle	Arbuckle	Arbuckle	Davis	Davis	Winters	Davis
Plot size	2.1 x 6.1 m		3.05 x 4.88 m		3.05 x 4.88 m	1.52 x 6.10 m	3.05 x 4.88 m	2.1 x 6.1 m	2.44 x 3.66 m
Application timing	A	B	A	B	----------				
Date	February 18, 2021	March 22, 2022	January 12, 2022	March 3, 2022	January 12, 2022	February 11, 2022	January 21, 2021	March 1, 2021	February 5,2021
Time	10:00am	11:00am	10:15am	11:10am	10:15am	10:50am	3:30pm	12:00pm	12:30pm
Type of sprayer	CO_2 back sprayer								
Boom size	4 nozzles 508 mm spacing	4 nozzles 508 mm spacing	3 nozzles 457 mm spacing	3 nozzles 457 mm spacing	3 nozzles 457 mm spacing	3 nozzles 457 mm spacing	3 nozzles 457 mm spacing	4 nozzles 508 mm spacing	2 nozzles 457 mm spacing
Type of nozzles	AIXR11003	AIXR110025	AIXR11002	AIXR11003	AIXR11003	AIXR11002	AIXR11004	AIXR11002	AIXR11002
Gallons per acre	20	20	25	25	25	25	30	20	20
Cloud cover	55%	85%	0%	20%	0%	0%	0%	0%	0%
Air temperature	10.4°C	13.8°C	11.2°C	20.7°C	11.2°C	16.9°C	16.4°C	13.3°C	13.3°C
Relative humidity	56%	63%	73%	53%	73%	66%	31%	55%	55%
Soil temperature	9.2°C	11.8°C	7.8°C	11.7°C	7.7°C	10.7°C	10.6°C	9.4°C	9.4°C
Wind speed kph	3.54	14.16	1.61	2.09	1.61	5.79	9.98	4.02	4.02
Wind direction	North	North	South	West	South	South	South	Southeast	Southeast
Soil texture	Loam		Sandy loam		Sandy loam	Sandy loam	Sandy loam	Loam	Loam
Soil organic matter	2.73		1.40		1.40	2.97	1.40	2.74	3.11
Soil pH	6.90		6.78		6.78	6.45	6.78	7.56	6.93

Table 5. Application details for a crop safety study in young almond, pistachio, and walnut trees evaluating high rates of pyroxasulfone and S-metolachlor near Davis, CA in spring 2021 and 2022.

	Almond[1], pistachio, and walnut Study 13-15		—— Almond —— Study 13		Pistachio and walnut Study 14 and 15
	—— 2021 ——		—— 2022 ——		
Application timing	A[2]	B	A	B	B
Plot size	------------------------------3.05 x 6.10 m-------------------------------				
Date	February 5,2021	March 12,2021	February 25, 2022	March 24, 2022	April 22, 2022
Time	10:30am	1:00pm	11:00am	11:40am	11:30am
Type of sprayer	----------------------------CO_2 back sprayer----------------------------				
Boom size	----------------------3 nozzles 457.2 mm spacing---------------------				
Type of nozzles	-------------------------------AIXR11003-------------------------------				
Gallons per acre	-------------------------------------20------------------------------------				
Cloud cover	----------------------------0%-------------------------				55%
Air temperature	8.5°C	18.8°C	11.7°C	25.6°C	19.4°C
Relative humidity	79%	24%	34%	43%	50%
Soil temperature at 2 in.	8.2°C	11.3°C	8.6°C	15.5°C	14.9°C
Wind speed kph	6.9	19.4	15.2	0	1.6
Wind direction	South	North	North	---------	West
Soil texture	--------------------------------Sandy loam------------------------------				
Soil organic matter	-------------------------------------1.52----------------------------------				
Soil pH	-------------------------------------6.79----------------------------------				

[1]The almond variety was Nonpareil. The pistachio variety was Kerman. The walnut variety was Chandler.
[2]Application “A” was applied before blooming and leafing. Application “B” was applied after blooming and leafing.

Table 6. Overall and dominant weed control with preemergence herbicides in a fall fallow field experiment conducted in 2020 and 2021 near Davis, CA.

			Fall 2020 (Study 1)[1]			Fall 2021 (Study 2)			
No.	Treatment	Rate	Overall	Overall	Filaree	Overall	Swinecress	Overall	Swinecress
			DAT[2]						
			30	75	75	30	30	75	75
		g a.i. ha^{-1}	% Control						
1	Pyroxasulfone	146	81	65 b	38	40 b	2 b	80	68
2	Pyroxasulfone	219	91	85 ab	53	42 b	30 b	79	89
3	Pyroxasulfone	293	91	81 ab	66	41 b	18 b	79	88
4	Indaziflam	52	93	90 a	65	70 a	76 a	91	93
5	Indaziflam	73	95	92 a	100	76 a	93 a	91	98
6	Pendimethalin	2,130	84	63 b	70	40 b	13 b	83	44
7	Pendimethalin	4,259	86	79 ab	63	41 b	10 b	85	58
	P-value		0.158	0.036	0.422	<0.0001	<0.0001	0.333	0.147

[1]There was no single dominant species at 30 DAT in Study 1.
[2]DAT = days after treatment

Table 7. Overall and dominant weed control with preemergence herbicides in a fallow field experiment conducted in spring (study 3) 2021 near Davis, CA.

No.	Treatment	Rate	Overall	Redroot pigweed	Common lambsquarters	Overall	Redroot pigweed	Common lambsquarters
			DAT[1]					
			30	30	30	60	60	60
		g a.i. ha^{-1}	% Control					
1	Pyroxasulfone	146	91	88	50	59	13	38 abc
2	Pyroxasulfone	219	90	75	63	42	13	63 ab
3	Pyroxasulfone	293	91	75	100	58	0	88 a
4	Indaziflam	52	92	25	63	41	25	25 bc
5	Indaziflam	73	95	38	88	56	13	38 abc
6	Pendimethalin	4,259	92	50	88	59	25	0 c
7	Pendimethalin	6,389	94	63	50	59	0	25 bc
	P-value		0.487	0.223	0.429	0.324	0.757	0.059

[1]DAT = days after treatment

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Table 8. Overall weed and yellow nutsedge control with preemergence herbicides in an irrigation incorporation experiment (study 5)[1] near Davis, CA in summer 2021.

No.	Treatment	Rate	Overall	Yellow nutsedge	Overall	Yellow nutsedge
			DAT-B[2]			
			90	90	150	150
		g a.i. ha^{-1}	% Control			
1	Pyroxasulfone	146	93	65	87	70
2	Pyroxasulfone	219	95	73	87	76
3	Pyroxasulfone	293	95	73	89	68
4	Indaziflam	52	92	40	89	64
5	Indaziflam	73	94	66	92	68
6	Pendimethalin	4,259	91	67	86	73
7	Pendimethalin	6,389	91	54	84	40
	P-value		0.095	0.523	0.085	0.772

[1]Analyzed as a randomized complete block design averaged over two irrigation incorporation timings (N =8).
[2]DAT-B = days after treatment "B" (five days before initial irrigation)

Table 9. Overall and dominant weed control with preemergence herbicides in a sequential application experiment conducted in a fallow field and almond orchard in spring 2021 and spring 2022 near Arbuckle and Davis, CA.

No.	Treatments	Timing[1]	Rate	Fallow field (study 6)		Young almonds (study 7)			
				Overall	Field bindweed	Overall	Field bindweed	Overall	Field bindweed
				DAT-B[2]					
				60	60	60	60	90	90
			g a.i. ha^{-1}	% Control					
1	Indaziflam	A	52	88	0	84	67	68	0
	Pendimethalin	B	4,259						
2	Indaziflam	A	52	80	23	88	33	72	0
	Pendimethalin	B	6,389						
3	Indaziflam	A	52	88	23	85	17	68	0
	Pyroxasulfone	B	146						
4	Indaziflam	A	52	82	10	87	33	62	0
	Pyroxasulfone	B	293						
5	Pyroxasulfone	A	146	87	50	87	33	52	0
	Pendimethalin	B	4,259						
6	Pyroxasulfone	A	146	90	40	87	67	62	33
	Pendimethalin	B	6,389						
7	Pyroxasulfone	A	293	87	23	95	33	82	33
	Pendimethalin	B	4,259						
8	Pyroxasulfone	A	293	77	10	93	67	82	0
	Pendimethalin	B	6,389						
9	Penoxsulam + Oxyfluorfen	A	29 + 1,379	80	0	88	33	70	0
	Pendimethalin	B	4,259						
10	Penoxsulam + Oxyfluorfen	A	29 + 1,379	91	27	91	33	73	33
	Pendimethalin	B	6,389						
11	Flumioxazin	A	358	95	68	87	93	70	33
	Pendimethalin	B	4,259						
12	Flumioxazin	A	358	87	0	90	0	82	33
	Pendimethalin	B	6,389						
	P-value			0.637	0.252	0.893	0.172	0.732	0.781

[1]Treatment timing "A" was applied on February 18, 202. Treatment timing "B" was applied on March 22, 2021.
[2]DAT-B = Days after treatment "B" timing

Table 10. Overall and dominant weed control in a single application orchard experiment conducted in almond and walnut orchards in spring 2022 near Arbuckle and Davis, CA.

			Young almond orchard (study 8)[1]			Walnut orchard (study 9)				
No.	Treatment	Rate	Overall	Overall	Field bindweed	Overall	Bermudagrass	Overall	Bermudagrass	Foxtail barely
			DAT[2]							
			30	60	60	30	30	60	60	60
		g a.i. ha^{-1}	% Control							
1	Indaziflam Glufosinate	29 984	98	90	67	84	75	50	25	50
2	Indaziflam Glufosinate	39 1,334	99	92	67	88	70	70	25	28
3	Indaziflam Glufosinate	49 1,704	100	91	0	88	73	82	25	77
4	Indaziflam Glufosinate	73 1,334	99	91	63	88	75	63	50	75
5	Pyroxasulfone Glufosinate	219 1,704	100	84	33	83	60	51	25	48
6	Pyroxasulfone Glufosinate	293 1,704	99	85	0	83	48	81	25	45
7	Pendimethalin Glufosinate	4,259 1,704	98	94	67	87	70	73	25	93
8	Pendimethalin Glufosinate	6,389 1,704	99	86	33	85	95	63	25	96
	P-value		0.678	0.415	0.445	0.975	0.921	0.670	0.996	0.607

[1]There was no single dominant species at 30 DAT in study 8.
[2]DAT = days after treatment

Table 11. Overall weed control 120 DAT with preemergence herbicides in an orchard and vineyard experiment near Davis and Winters, CA in spring 2021.

No.	Treatment	Rate	Almond orchard (study 10)	Almond orchard (study 11)	Vineyard (study 12)
			120 DAT[1]		
		g a.i. ha^{-1}	----------------% Control-----------------		
1	Indaziflam	56	85	88	96
2	Rimsulfuron	70	92	86	99
3	Flumioxazin	882	87	96	98
4	Pendimethalin	4,259	93	96	97
5	Pyroxasulfone	150	92	94	99
6	Pyroxasulfone	225	88	93	99
7	Pyroxasulfone	300	89	91	98
8	Pyroxasulfone Pendimethalin	150 4,259	90	73	98
9	Pyroxasulfone Pendimethalin	225 4,259	96	94	96
10	Flumioxazin Pyroxasulfone	118 150	93	94	99
11	Flumioxazin Pyroxasulfone	178 225	96	91	98
12	Pyroxasulfone Rimsulfuron	150 70	92	93	99
13	Pyroxasulfone Rimsulfuron	225 70	90	93	99
14	Oxyfluorfen Penoxsulam	2,018 4,261	85	93	98
	P-value		0.672	0.580	0.937

[1] DAT= days after treatment

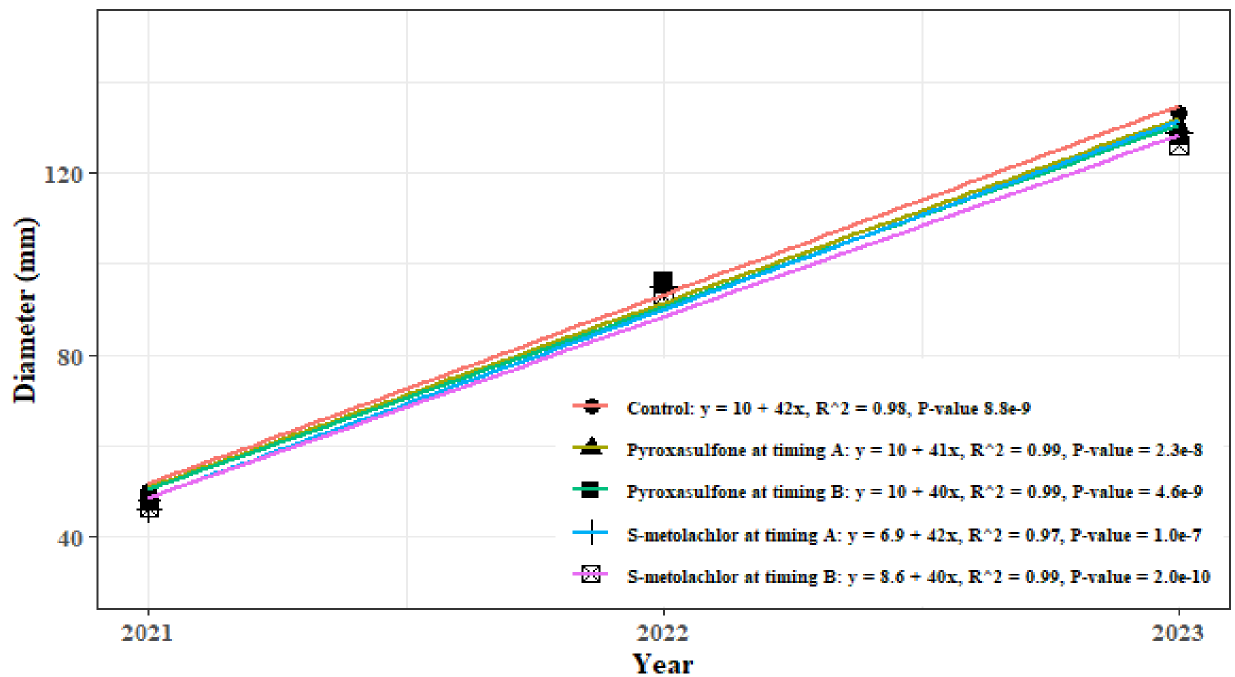

Figure 1. Young almond tree response to pyroxasulfone and S-metolachlor.
Diameter measurements of almond trees before study initation, one year after treatment (2022), and two years after initial treatment (2023). No differences were found among treatments compared to the control. Application rates were pyroxasulfone at 1,199 g a.i. ha^{-1} and S-metolachlor at 14,010 g a.i. ha^{-1}. Timing “A” was before flowering and leafing, and timing “B” was after flowering and leafing.

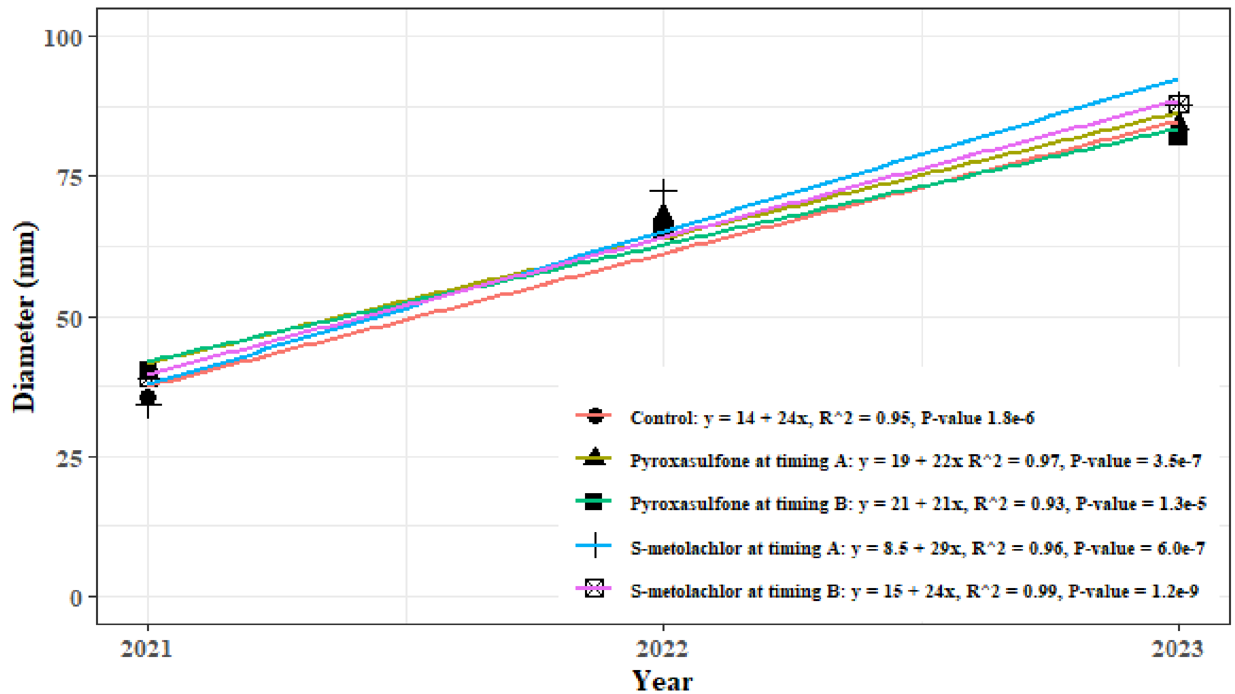

Figure 2. Young walnut tree response to pyroxasulfone and S-metolachlor.
Diameter measurements of walnut trees before study initation, one year after treatment (2022), and two years after initial treatment (2023). No differences were found among treatments compared to the control. Application rates were pyroxasulfone at 1,199 g a.i.. ha^{-1} and S-metolachlor at 14,010 g a.i. ha^{-1}. Timing “A” was before flowering and leafing, and timing “B” was after flowering and leafing.

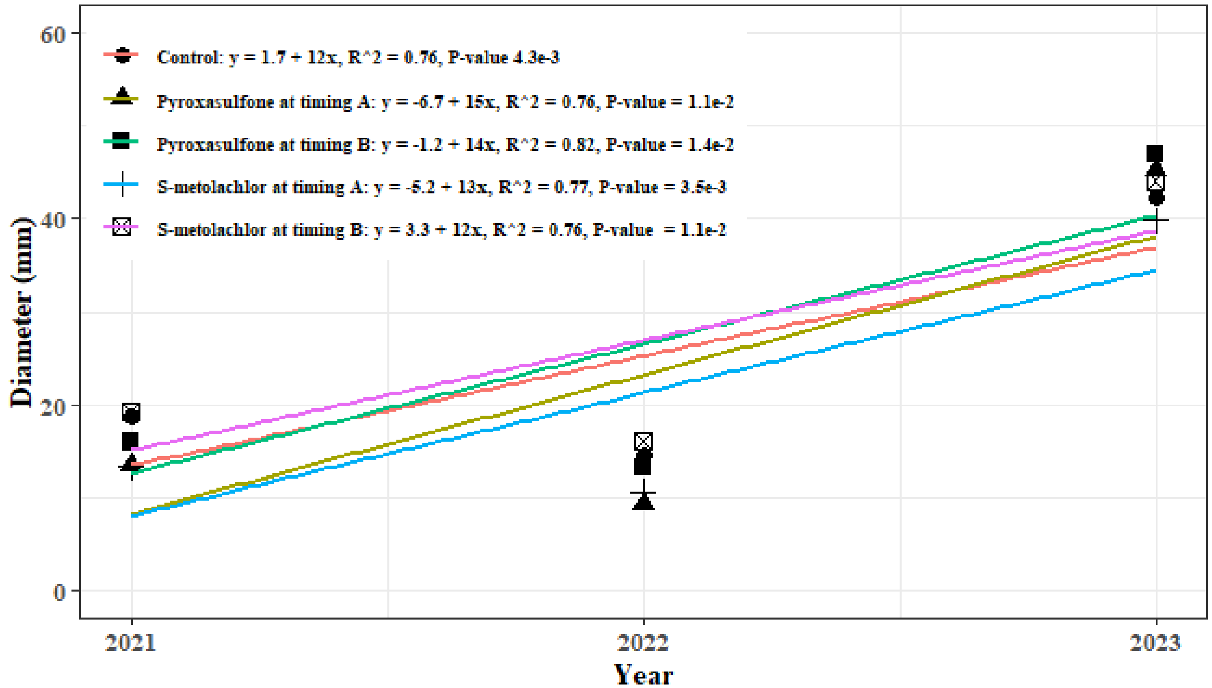

Figure 3. Young pistachio tree response to pyroxasulfone and S-metolachlor.
Diameter measurements of pistachio trees before study initation, one year after treatment (2022), and two years after initial treatment (2023). No differences were found among treatments compared to the control. Application rates were pyroxasulfone at 1,199 g a.i. ha^{-1} and S-metolachlor at 14,010 g a.i. ha^{-1}. Timing "A" was before flowering and leafing, and timing "B" was after flowering and leafing.

Appendix

Weeds observed:

annual bluegrass (*Poa annua*)

annual sowthistle (*Sonchus oleraceus*)

black nightshade (*Solanum nigrum*)

bermudagrass (*Cynodon dactylon*)

California burclover (*Medicago polymorpha*)

common lambsquarters (*Chenopodium album*)

common knotweed (*Polygonum arenastrum*)

crabgrass (*Digitaria sanguinalis*)

field bindweed (*Convolvulus arvensis*)

filaree (*Erodium cicutarium*)

foxtail barley (*Hordeum jubatum*)

hare barley (*Hordeum murinum*)

hairy fleabane (*Erigeran bonariensis*),

henbit (*Lamium amplexicaule*)

Italian ryegrass (*Lolium multiflorum*)

knotweed (*Polygonum arenastrum*)

malva (*Malva parviflora*)

prostrate pigweed (*Amaranthus blitoides*)

shepherd's purse (*Capsella bursa-pastoris*)

spotted spurge (*Euphorbia maculata*)

square willowherb (*Epilobium tetragonum*)

swinecress (*Lepidium coronopus*)

redroot pigweed (*Amaranthus retroflexus*)

ryegrass (*Lolium spp.*)

yellow nutsedge (*Cyperus esculentus*)

wild parsley (*Pastinaca sativa*)

Appendix table 1. Overall control in a fallow field study with preemergence herbicides near Davis, CA in fall 2020 (study 1).

No.	Treatment	Rate	DAT[1]					
			30	60	75		90	105
		g a.i. ha^{-1}	--------------------------% Control--------------------------					
1	Pyroxasulfone	146	81	75	65	b	68	56
2	Pyroxasulfone	219	91	88	85	ab	83	78
3	Pyroxasulfone	293	91	91	81	ab	78	71
4	Indaziflam	52	93	94	90	a	90	83
5	Indaziflam	73	95	92	92	a	90	87
6	Pendimethalin	2,130	84	83	63	b	74	64
7	Pendimethalin	4,259	86	90	79	ab	80	75
	P-value		0.158	0.376	0.036		0.508	0.572

[1]DAT= days after treatment

Appendix table 2. Control of shepherd's purse in a fallow field study with preemergence herbicides near Davis, CA in fall 2020 (study 1).

No.	Treatment	Rate	DAT[1]			
			60	75	90	105
		g a.i. ha^{-1}	--------------------% Control------------------			
1	Pyroxasulfone	146	73	38	46	43
2	Pyroxasulfone	219	84	74	78	73
3	Pyroxasulfone	293	85	73	75	73
4	Indaziflam	52	93	85	93	88
5	Indaziflam	73	94	100	100	100
6	Pendimethalin	2,130	75	68	55	63
7	Pendimethalin	4,259	84	63	69	65
	P-value		0.709	0.166	0.194	0.127

[1]DAT= days after treatment

Appendix table 3. Control of filaree in a fallow field study with preemergence herbicides near Davis, CA in fall 2020 (study 1).

No.	Treatment	Rate	DAT[1]			
			60	75	90	105
		g a.i. ha^{-1}	--------------------% Control------------------			
1	Pyroxasulfone	146	80	38	58	44
2	Pyroxasulfone	219	93	53	73	59
3	Pyroxasulfone	293	91	66	63	55
4	Indaziflam	52	95	65	95	81
5	Indaziflam	73	100	100	90	85
6	Pendimethalin	2,130	85	70	68	38
7	Pendimethalin	4,259	94	63	73	60
	P-value		0.709	0.166	0.194	0.127

[1]DAT= days after treatment

Appendix table 4. Control of annual bluegrass in a fallow field study with preemergence herbicides near Davis, CA in fall 2020 (study 1).

No.	Treatment	Rate	DAT[1]		
			75	90	105
		g a.i. ha^{-1}	-----------% Control------------		
1	Pyroxasulfone	146	38	58	44
2	Pyroxasulfone	219	53	73	59
3	Pyroxasulfone	293	66	63	55
4	Indaziflam	52	65	95	81
5	Indaziflam	73	100	90	85
6	Pendimethalin	2,130	70	68	38
7	Pendimethalin	4,259	63	73	60
	P-value		0.166	0.194	0.127

[1]DAT= days after treatment

Appendix table 5. Control of henbit in a fallow field study with preemergence herbicides near Davis, CA in fall 2020 (study 1).

No.	Treatment	Rate	DAT[1]			
			60	75	90	105
		g a.i. ha^{-1}	-------------------% Control------------------			
1	Pyroxasulfone	146	84	38	70	90
2	Pyroxasulfone	219	84	65	70	55
3	Pyroxasulfone	293	90	79	70	50
4	Indaziflam	52	94	78	83	40
5	Indaziflam	73	96	75	60	60
6	Pendimethalin	2,130	75	68	90	100
7	Pendimethalin	4,259	91	50	100	100
	P-value		0.836	0.777	0.584	0.375

[1]DAT= days after treatment

Appendix table 6. Control of square willowherb in a fallow field study with preemergence herbicides near Davis, CA in fall 2020 (study 1).

No.	Treatment	Rate	DAT[1]			
			60	75	90	105
		g a.i. ha^{-1}	----------------------% Control------------------			
1	Pyroxasulfone	146	65	60	68	75
2	Pyroxasulfone	219	90	85	38	33
3	Pyroxasulfone	293	98	75	75	80
4	Indaziflam	52	96	79	90	88
5	Indaziflam	73	78	100	100	100
6	Pendimethalin	2,130	95	75	73	60
7	Pendimethalin	4,259	90	67	75	80
	P-value		0.456	0.466	0.442	0.378

[1]DAT= days after treatment

Appendix table 7. Overall weed control in a fallow field study with preemergence herbicides near Davis, CA in fall 2021 (study 2).

No.	Treatment	Rate	DAT[1]				
			30		60	75	
		g a.i. ha^{-1}	---% Control---				
1	Pyroxasulfone	146	40	b	89	80	
2	Pyroxasulfone	219	42	b	88	79	
3	Pyroxasulfone	293	41	b	89	79	
4	Indaziflam	52	70	a	97	91	
5	Indaziflam	73	76	a	98	91	
6	Pendimethalin	2,130	40	b	86	83	
7	Pendimethalin	4,259	41	b	90	85	
	P-value		<0.0001		0.278	0.333	

[1]DAT= days after treatment

Appendix table 8. Control of field bindweed in a fallow field study with preemergence herbicides near Davis, CA in fall 2021 (study 2).

No.	Treatment	Rate	DAT[1]		
			60	75	
		g a.i. ha^{-1}	---% Control---		
1	Pyroxasulfone	146	0	0	b
2	Pyroxasulfone	219	50	0	b
3	Pyroxasulfone	293	25	0	b
4	Indaziflam	52	50	25	ab
5	Indaziflam	73	50	0	b
6	Pendimethalin	2,130	75	68	a
7	Pendimethalin	4,259	75	65	a
	P-value		0.373	0.007	

[1]DAT= days after treatment

Appendix table 9. Control of malva in a fallow field study with preemergence herbicides near Davis, CA in fall 2021 (study 2).

No.	Treatment	Rate	DAT[1]		
			30	60	75
		g a.i. ha^{-1}	---% Control---		
1	Pyroxasulfone	146	65	73	78
2	Pyroxasulfone	219	23	75	46
3	Pyroxasulfone	293	43	90	50
4	Indaziflam	52	83	100	100
5	Indaziflam	73	78	100	100
6	Pendimethalin	2,130	55	100	100
7	Pendimethalin	4,259	55	75	100
	P-value		0.348	0.720	0.072

[1]DAT= days after treatment

Appendix table 10. Control of swinecress in a fallow field study with preemergence herbicides near Davis, CA in fall 2021 (study 2).

No.	Treatment	Rate	DAT[1]			
			30		60	75
		g a.i. ha^{-1}	% Control			
1	Pyroxasulfone	146	20	b	50	68
2	Pyroxasulfone	219	30	b	60	89
3	Pyroxasulfone	293	18	b	63	88
4	Indaziflam	52	76	a	73	93
5	Indaziflam	73	93	a	100	98
6	Pendimethalin	2,130	13	b	25	44
7	Pendimethalin	4,259	10	b	60	58
	P-value		<0.0001		0.406	0.147

[1]DAT= days after treatment

Appendix table 11. Overall weed control in a fallow field study with preemergence herbicides near Davis, CA in spring 2021 (study 3).

No.	Treatment	Rate	DAT[1]		
			30	45	60
		g a.i. ha^{-1}	% Control		
1	Pyroxasulfone	146	91	88	59
2	Pyroxasulfone	219	90	78	42
3	Pyroxasulfone	293	91	81	58
4	Indaziflam	52	92	80	41
5	Indaziflam	73	95	85	56
6	Pendimethalin	4,259	92	85	59
7	Pendimethalin	6,389	94	88	59
	P-value		0.487	0.230	0.324

[1]DAT= days after treatment

Appendix table 12. Control of common lambsquarters in a fallow field study with preemergence herbicides near Davis, CA in spring 2021 (study 3).

No.	Treatment	Rate	DAT[1]			
			30	45	60	
		g a.i. ha^{-1}	% Control			
1	Pyroxasulfone	146	50	38	38	abc
2	Pyroxasulfone	219	63	63	63	ab
3	Pyroxasulfone	293	100	100	88	a
4	Indaziflam	52	63	25	25	bc
5	Indaziflam	73	88	63	38	abc
6	Pendimethalin	4,259	88	25	0	c
7	Pendimethalin	6,389	50	25	25	bc
	P-value		0.429	0.063	0.059	

[1]DAT= days after treatment

Appendix table 13. Control of redroot pigweed in a fallow field study with preemergence herbicides near Davis, CA in spring 2021 (study 3).

No.	Treatment	Rate	DAT[1]		
			30		
		g a.i. ha^{-1}	-------------% Control-------------		
1	Pyroxasulfone	146	88	63	13
2	Pyroxasulfone	219	75	28	13
3	Pyroxasulfone	293	75	0	0
4	Indaziflam	52	25	13	25
5	Indaziflam	73	38	13	13
6	Pendimethalin	4,259	50	13	25
7	Pendimethalin	6,389	63	13	0
	P-value		0.223	0.190	0.757

[1]DAT= days after treatment

Appendix table 14. Control of prostrate pigweed in a fallow field study with preemergence herbicides near Davis, CA in spring 2021 (study 3).

No.	Treatment	Rate	DAT[1]		
			30	45	60
		g a.i. ha^{-1}	-------------% Control-------------		
1	Pyroxasulfone	146	55	38	43
2	Pyroxasulfone	219	63	25	13
3	Pyroxasulfone	293	50	25	25
4	Indaziflam	52	38	13	13
5	Indaziflam	73	63	50	25
6	Pendimethalin	4,259	63	37	25
7	Pendimethalin	6,389	75	75	50
	P-value		0.960	0.419	0.850

[1]DAT= days after treatment

Appendix table 15. Control of field bindweed in a fallow field study with preemergence herbicides near Davis, CA in spring 2021 (study 3).

No.	Treatment	Rate	DAT[1]		
			30	45	60
		g a.i. ha^{-1}	-------------% Control-------------		
1	Pyroxasulfone	146	88	30	25
2	Pyroxasulfone	219	75	0.0	0
3	Pyroxasulfone	293	75	43	25
4	Indaziflam	52	25	35	0
5	Indaziflam	73	38	35	0
6	Pendimethalin	4,259	50	17	0
7	Pendimethalin	6,389	63	13	0
	P-value		0.598	0.624	0.558

[1]DAT= days after treatment

Appendix table 16. Overall weed control in a fallow field study with preemergence herbicides near Davis, CA. in spring 2022[1] (study 4).

No.	Treatment	Rate	DAT[2] 30		DAT[2] 45		DAT[2] 60	
		g a.i. ha^{-1}	---------------% Control-------------					
1	Pyroxasulfone	146	86		59	ab	10	c
2	Pyroxasulfone	219	79		59	ab	21	bc
3	Pyroxasulfone	293	84		50	bc	3	c
4	Indaziflam	52	83		34	c	10	c
5	Indaziflam	73	84		44	bc	10	c
6	Pendimethalin	4,259	90		71	a	40	ab
7	Pendimethalin	6,389	91		78	a	55	a
	P-value		0.402		0.004		<0.0001	

[1]During the spray application, a spray pressure problem occurred during application of treatments with pyroxasulfone at 293 g ha^{-1}, indaziflam at 52 and 53 g ha^{-1}.
[2]DAT= days after treatment

Appendix table 17. Control of common lambsquarters in a fallow field study with preemergence herbicides near Davis, CA. in spring 2022[1] (study 4).

No.	Treatment	Rate	DAT[2] 30		DAT[2] 45		DAT[2] 60	
		g a.i. ha^{-1}	---------------% Control-------------					
1	Pyroxasulfone	146	60	ab	43	b	33	b
2	Pyroxasulfone	219	55	abc	53	b	25	b
3	Pyroxasulfone	293	53	abc	40	b	23	b
4	Indaziflam	52	20	c	5	c	5	b
5	Indaziflam	73	54	abc	63	ab	10	b
6	Pendimethalin	4,259	89	ab	65	ab	70	a
7	Pendimethalin	6,389	90	a	80	a	73	a
	P-value		0.013		<0.0001		<0.0001	

[1]During the spray application, a spray pressure problem occurred during application of treatments with pyroxasulfone at 293 g ha^{-1}, indaziflam at 52 and 53 g ha^{-1}.
[2]DAT= days after treatment

Appendix table 18. Control of prostrate pigweed in a fallow field study with preemergence herbicides near Davis, CA. in spring 2022[1] (study 4).

No.	Treatment	Rate	DAT[2]				
			30	45		60	
		g a.i. ha^{-1}	---------------% Control-------------				
1	Pyroxasulfone	146	70	20	c	0	b
2	Pyroxasulfone	219	66	50	bc	28	b
3	Pyroxasulfone	293	59	18	c	13	b
4	Indaziflam	52	81	50	bc	18	b
5	Indaziflam	73	79	28	c	20	b
6	Pendimethalin	4,259	99	85	ab	83	a
7	Pendimethalin	6,389	99	98	a	83	a
	P-value		0.154	<0.0001		<0.0001	

[1]During the spray application, a spray pressure problem occurred during application of treatments with pyroxasulfone at 293 g ha^{-1}, indaziflam at 52 and 53 g ha^{-1}.
[2]DAT= days after treatment

Appendix table 19. Control of redroot pigweed in a fallow field study with preemergence herbicides near Davis, CA. in spring 2022[1] (study 4).

No.	Treatment	Rate	DAT[2]				
			30		45		60
		g a.i. ha^{-1}	---------------% Control-------------				
1	Pyroxasulfone	146	38	ab	28	bc	10
2	Pyroxasulfone	219	60	a	33	abc	23
3	Pyroxasulfone	293	58	a	50	ab	33
4	Indaziflam	52	0	b	3	c	0
5	Indaziflam	73	0	b	8	c	0
6	Pendimethalin	4,259	35	ab	40	abc	8
7	Pendimethalin	6,389	51	a	70	a	45
	P-value		0.047		0.017		0.081

[1]During the spray application, a spray pressure problem occurred during application of treatments with pyroxasulfone at 293 g ha^{-1}, indaziflam at 52 and 53 g ha^{-1}.
[2]DAT= days after treatment

Appendix table 20-A. Overall weed control with pyroxasulfone, indaziflam, and pendimethalin as affected by incorporation timing in a study near Davis, CA in summer 2021 (study 5).

No.	Treatment	Rate	Application Timing[1]	DAT-B[2]						
				30	45	75	90	120	150	180
		g a.i. ha^{-1}		% Control						
1	Pyroxasulfone	146	A	100	98	94	92	91	86	82
2	Pyroxasulfone	146	B	100	96	96	94	91	88	85
3	Pyroxasulfone	219	A	100	96	95	95	95	84	95
4	Pyroxasulfone	219	B	100	97	96	95	94	89	79
5	Pyroxasulfone	293	A	100	98	96	95	94	90	86
6	Pyroxasulfone	293	B	100	100	97	95	98	88	88
7	Indaziflam	52	A	100	99	95	92	91	86	92
8	Indaziflam	52	B	100	95	92	92	81	91	87
9	Indaziflam	73	A	100	97	95	92	93	93	95
10	Indaziflam	73	B	100	100	99	96	94	91	93
11	Pendimethalin	4,259	A	100	97	93	90	90	85	83
12	Pendimethalin	4,259	B	100	96	92	93	91	86	80
13	Pendimethalin	6,389	A	100	97	91	90	89	86	80
14	Pendimethalin	6,389	B	100	100	93	91	87	83	80
	Interaction p-value			1	0.077	0.275	0.836	0.062	0.050	0.875
	Irrigation p-value			1	0.855	0.305	0.209	0.271	0.672	0.482

[1]The two applications timings were 18 days before irrigation (timing A) and 5 days before irrigation (timing B).
[2]DAT-B = days after treatment B

Appendix table 20-B. Overall weed control with pyroxasulfone, indaziflam, and pendimethalin in a study near Davis, CA in summer 2021 (study 5); analyzed as a randomized complete block design averaged over two irrigation incorporation timings[1].

No.	Treatment	Rate	DAT-B[2]								
			30	45	75	90	120		150	180	
		g a.i. ha^{-1}	% Control								
1	Pyroxasulfone	146	100	97	95	93	91	ab	87	83	bcd
2	Pyroxasulfone	219	100	96	95	95	94	a	87	82	cd
3	Pyroxasulfone	293	100	99	96	95	95	a	89	87	abc
4	Indaziflam	52	100	97	93	92	86	b	89	90	ab
5	Indaziflam	73	100	99	97	94	93	a	92	94	a
6	Pendimethalin	4,259	100	97	92	91	91	ab	86	81	cd
7	Pendimethalin	6,389	100	98	92	91	88	b	84	80	d
	Herbicide p-value		1	0.353	0.095	0.095	0.013		0.085	0.001	

[1]Analysis of herbicide main effects was done as randomized complete block design averaged over incorporation timing (N=8) to identify differences among herbicide treatments.
[2]DAT-B = days after treatment B

Appendix table 21-A. Control of black nightshade[1] with pyroxasulfone, indaziflam, and pendimethalin as affected by incorporation timing in a study near Davis, CA in summer 2021 (study 5).

No.	Treatment	Rate	Application Timing[2]	DAT-B[3] 75	90	120	150
		g a.i. ha^{-1}		--------------% Control--------------			
1	Pyroxasulfone	146	A	88	100	100	100
2	Pyroxasulfone	146	B	100	100	78	93
3	Pyroxasulfone	219	A	88	93	100	100
4	Pyroxasulfone	219	B	100	100	100	100
5	Pyroxasulfone	293	A	100	100	100	100
6	Pyroxasulfone	293	B	100	100	100	83
7	Indaziflam	52	A	88	93	93	100
8	Indaziflam	52	B	93	93	93	100
9	Indaziflam	73	A	83	88	93	93
10	Indaziflam	73	B	100	100	100	75
11	Pendimethalin	4,259	A	64	63	50	75
12	Pendimethalin	4,259	B	75	75	93	93
13	Pendimethalin	6,389	A	73	73	87	100
14	Pendimethalin	6,389	B	95	93	100	83
	Interaction p-value			0.999	0.616	0.040	0.669
	Irrigation p-value			0.362	0.207	0.283	0.386

[1]Black nightshade began to senesce approximately 180DAT-B.
[2]The two applications timings were 18 days before irrigation (timing A) and 5 days before irrigation (timing B).
[3]DAT-B = days after treatment B

Appendix table 21-B. Control of black nightshade[1] with pyroxasulfone, indaziflam, and pendimethalin in a study near Davis, CA in summer 2021 (study 5); analyzed as a randomized complete block design averaged over two irrigation incorporation timings[2].

No.	Treatment	Rate	DAT-B[3] 75	90	120		150
		g a.i. ha^{-1}	-----------------% Control---------------				
1	Pyroxasulfone	146	95	93	91	ab	87
2	Pyroxasulfone	219	95	95	94	a	87
3	Pyroxasulfone	293	96	95	95	a	89
4	Indaziflam	52	93	92	86	b	89
5	Indaziflam	73	97	94	93	a	92
6	Pendimethalin	4,259	92	91	91	ab	86
7	Pendimethalin	6,389	92	91	88	b	84
	Herbicide p-value		0.095	0.095	0.013		0.085

[1]Black nightshade began to senesce approximately 180DAT-B.
[2]Analysis of herbicide main effects was done as randomized complete block design averaged over incorporation timing (N=8) to identify differences among herbicide treatments.
[3]DAT-B = days after treatment B

Appendix table 22-A. Control of malva with pyroxasulfone, indaziflam, and pendimethalin as affected by incorporation timing in a study near Davis, CA in summer 2021 (study 5).

No.	Treatment	Rate	Application Timing[1]	DAT-B[2] 120	150	180
		g a.i. ha^{-1}		----------% Control--------		
1	Pyroxasulfone	146	A	88	100	100
2	Pyroxasulfone	146	B	100	100	78
3	Pyroxasulfone	219	A	88	93	100
4	Pyroxasulfone	219	B	100	100	100
5	Pyroxasulfone	293	A	100	100	100
6	Pyroxasulfone	293	B	100	100	100
7	Indaziflam	52	A	88	93	93
8	Indaziflam	52	B	93	93	93
9	Indaziflam	73	A	83	88	93
10	Indaziflam	73	B	100	100	100
11	Pendimethalin	4,259	A	64	63	50
12	Pendimethalin	4,259	B	75	75	93
13	Pendimethalin	6,389	A	73	73	87
14	Pendimethalin	6,389	B	95	93	100
	Interaction p-value			0.999	0.616	0.040
	Irrigation p-value			0.362	0.207	0.283

[1]The two applications timings were 18 days before irrigation (timing A) and 5 days before irrigation (timing B).
[2]DAT-B = days after treatment B

Appendix table 22-B. Control of malva with pyroxasulfone, indaziflam, and pendimethalin in a study near Davis, CA in summer 2021 (study 5); analyzed as a randomized complete block design averaged over two irrigation incorporation timings[1].

No.	Treatment	Rate	DAT-B[2] 75	90		105
		g a.i. ha^{-1}	------------% Control------------			
1	Pyroxasulfone	146	94	83	c	89
2	Pyroxasulfone	219	100	93	ab	85
3	Pyroxasulfone	293	100	96	ab	73
4	Indaziflam	52	100	100	a	98
5	Indaziflam	73	100	98	ab	100
6	Pendimethalin	4,259	94	91	b	60
7	Pendimethalin	6,389	100	95	ab	74
	Herbicide p-value		0.550	0.001		0.087

[1]Analysis of herbicide main effects was done as randomized complete block design averaged over incorporation timing (N=8) to identify differences among herbicide treatments.
[2]DAT-B = days after treatment B

Appendix table 23-A. Control of yellow nutsedge with pyroxasulfone, indaziflam, and pendimethalin as affected by incorporation timing in a study near Davis, CA in summer 2021 (study 5).

No.	Treatment	Rate	Application Timing[1]	DAT-B[2]						
				30	45	75	90	120	150	180
		g a.i. ha^{-1}		% Control						
1	Pyroxasulfone	146	A	100	75	75	65	65	63	75
2	Pyroxasulfone	146	B	100	75	68	65	65	78	68
3	Pyroxasulfone	219	A	100	100	80	78	93	75	75
4	Pyroxasulfone	219	B	100	100	68	68	68	78	75
5	Pyroxasulfone	293	A	100	100	63	70	50	80	75
6	Pyroxasulfone	293	B	100	100	78	75	88	55	55
7	Indaziflam	52	A	100	75	58	55	38	53	88
8	Indaziflam	52	B	100	100	50	25	32	75	75
9	Indaziflam	73	A	100	100	58	58	55	60	100
10	Indaziflam	73	B	100	100	83	75	68	75	75
11	Pendimethalin	4,259	A	100	100	83	73	55	65	75
12	Pendimethalin	4,259	B	100	100	58	63	45	80	75
13	Pendimethalin	6,389	A	100	100	38	59	38	30	100
14	Pendimethalin	6,389	B	100	100	43	50	38	50	50
	Interaction p-value			1	0.885	0.941	0.826	0.577	0.659	0.909
	Irrigation p-value			1	0.718	0.930	0.574	0.880	0.301	0.247

[1]The two applications timings were 18 days before irrigation (timing A) and 5 days before irrigation (timing B).
[2]DAT-B = days after treatment B

Appendix table 23-B. Control of yellow nutsedge with pyroxasulfone, indaziflam, and pendimethalin in a study near Davis, CA in summer 2021 (study 5); analyzed as a randomized complete block design averaged over two irrigation incorporation timings[1].

No.	Treatment	Rate	DAT-B[2]						
			30	45	75	90	120	150	180
		g a.i. ha^{-1}	% Control						
1	Pyroxasulfone	146	100	75	81	65	65	70	71
2	Pyroxasulfone	219	100	100	84	73	80	76	75
3	Pyroxasulfone	293	100	100	80	73	69	68	65
4	Indaziflam	52	100	88	54	40	35	64	81
5	Indaziflam	73	100	100	70	66	61	68	88
6	Pendimethalin	4,259	100	100	70	67	50	73	75
7	Pendimethalin	6,389	100	100	40	54	38	40	75
	Herbicide p-value		1	0.168	0.641	0.523	0.257	0.772	0.970

[1]Analysis of herbicide main effects was done as randomized complete block design averaged over incorporation timing (N=8) to identify differences among herbicide treatments.
[2]DAT-B = days after treatment B

Appendix table 24-A. Control of common lambsquarters with pyroxasulfone, indaziflam, and pendimethalin as affected by incorporation timing in a study near Davis, CA in summer 2021 (study 5).

No.	Treatment	Rate	Application Timing[1]	DAT-B[2]				
				30	45	75	90	120
		g a.i. ha^{-1}		% Control				
1	Pyroxasulfone	146	A	100	100	88	88	100
2	Pyroxasulfone	146	B	100	75	100	100	93
3	Pyroxasulfone	219	A	100	75	100	100	100
4	Pyroxasulfone	219	B	100	100	100	100	100
5	Pyroxasulfone	293	A	100	100	100	100	100
6	Pyroxasulfone	293	B	100	100	100	100	93
7	Indaziflam	52	A	100	100	100	100	100
8	Indaziflam	52	B	100	100	100	100	100
9	Indaziflam	73	A	100	75	100	100	100
10	Indaziflam	73	B	100	100	100	100	100
11	Pendimethalin	4,259	A	100	100	88	100	85
12	Pendimethalin	4,259	B	100	100	88	80	93
13	Pendimethalin	6,389	A	100	100	88	100	93
14	Pendimethalin	6,389	B	100	100	100	100	88
	Interaction p-value			1	0.384	0.994	0.080	0.234
	Irrigation p-value			1	0.601	0.592	0.753	0.633

[1]The two applications timings were 18 days before irrigation (timing A) and 5 days before irrigation (timing B).
[2]DAT-B = days after treatment B

Appendix table 24-B. Control of common lambsquarters with pyroxasulfone, indaziflam, and pendimethalin in a study near Davis, CA in summer 2021 (study 5); analyzed as a randomized complete block design[2] averaged over two irrigation incorporation timings[1].

No.	Treatment	Rate	DAT-B[2]				
			30	45	75	90	120
		g a.i. ha^{-1}	% Control				
1	Pyroxasulfone	146	100	88	94	94	96
2	Pyroxasulfone	219	100	88	100	100	100
3	Pyroxasulfone	293	100	100	100	100	96
4	Indaziflam	52	100	100	100	100	100
5	Indaziflam	73	100	88	100	100	100
6	Pendimethalin	4,259	100	100	88	90	89
7	Pendimethalin	6,389	100	100	94	100	90
	Herbicide p-value		1	0.677	0.339	0.240	0.191

[1]Analysis of herbicide main effects was done as randomized complete block design averaged over incorporation timing (N=8) to identify differences among herbicide treatments.
[2]DAT-B = days after treatment B

Appendix table 25-A. Control of redroot pigweed[1] with pyroxasulfone, indaziflam, and pendimethalin as affected by incorporation timing in a study near Davis, CA in summer 2021 (study 5).

No.	Treatment	Rate	Application Timing[2]	DAT-B[3]		
				30	45	75
		g a.i. ha^{-1}		----------% Control--------		
1	Pyroxasulfone	146	A	100	50	100
2	Pyroxasulfone	146	B	100	50	100
3	Pyroxasulfone	219	A	100	25	88
4	Pyroxasulfone	219	B	100	75	100
5	Pyroxasulfone	293	A	100	75	88
6	Pyroxasulfone	293	B	100	75	100
7	Indaziflam	52	A	100	75	100
8	Indaziflam	52	B	100	25	100
9	Indaziflam	73	A	100	50	100
10	Indaziflam	73	B	100	100	100
11	Pendimethalin	4,259	A	100	75	100
12	Pendimethalin	4,259	B	100	50	100
13	Pendimethalin	6,389	A	100	50	88
14	Pendimethalin	6,389	B	100	75	100
	Interaction p-value			1	0.290	0.980
	Irrigation p-value			1	0.731	0.357

[1]Redroot pigweed began to senesce approximately 90DAT.
[2]The two applications timings were 18 days before irrigation (timing A) and 5 days before irrigation (timing B).
[3]DAT-B = days after treatment B

Appendix table 25-B. Control of redroot pigweed[1] with pyroxasulfone, indaziflam, and pendimethalin in a study near Davis, CA in summer 2021 (study 5); analyzed as a randomized complete block design averaged over two irrigation incorporation timings[2].

No.	Treatment	Rate	DAT-B[3]		
			75	90	105
		g a.i. ha^{-1}	------------% Control------------		
1	Pyroxasulfone	146	100	50	100
2	Pyroxasulfone	219	100	50	94
3	Pyroxasulfone	293	100	75	94
4	Indaziflam	52	100	50	100
5	Indaziflam	73	100	75	100
6	Pendimethalin	4,259	100	63	100
7	Pendimethalin	6,389	100	63	94
	Herbicide p-value		1	0.88	0.677

[1]Redroot pigweed began to senesce approximately 90DAT.
[2]Analysis of herbicide main effects was done as randomized complete block design (RCBD) averaged over incorporation timing (N=8) to identify differences among herbicide treatments.
[3]DAT-B = days after treatment B

Appendix table 26-A. Control of prostrate pigweed[1] with pyroxasulfone, indaziflam, and pendimethalin as affected by incorporation timing in a study near Davis, CA in summer 2021 (study 5).

No.	Treatment	Rate	Application Timing[1]	DAT-B[2] 30	45	75	90	120
		g a.i. ha^{-1}		----------------------% Control----------------------				
1	Pyroxasulfone	146	A	100	100	100	88	100
2	Pyroxasulfone	146	B	100	100	100	100	100
3	Pyroxasulfone	219	A	100	100	100	100	88
4	Pyroxasulfone	219	B	100	100	100	100	100
5	Pyroxasulfone	293	A	100	100	100	100	88
6	Pyroxasulfone	293	B	100	100	100	100	100
7	Indaziflam	52	A	100	100	100	100	88
8	Indaziflam	52	B	100	100	100	100	75
9	Indaziflam	73	A	100	100	100	100	100
10	Indaziflam	73	B	100	100	100	100	100
11	Pendimethalin	4,259	A	100	100	100	100	100
12	Pendimethalin	4,259	B	100	100	100	100	100
13	Pendimethalin	6,389	A	100	100	100	100	90
14	Pendimethalin	6,389	B	100	100	100	100	100
	Interaction p-value			1	1	1	0.455	0.427
	Irrigation p-value			1	1	1	0.391	0.450

[1]Prostrate pigweed began to senesce approximately 150DAT-B.
[2]The two applications timings were 18 days before irrigation (timing A) and 5 days before irrigation (timing B).
[3]DAT-B = days after treatment B

Appendix table 26-B. Control of prostrate pigweed[1] with pyroxasulfone, indaziflam, and pendimethalin in a study near Davis, CA in summer 2021 (study 5); analyzed as a randomized complete block design averaged over two irrigation incorporation timings[2].

No.	Treatment	Rate	DAT-B[3] 30	45	75	90	120
		g a.i. ha^{-1}	----------------------% Control----------------------				
1	Pyroxasulfone	146	100	88	94	94	96
2	Pyroxasulfone	219	100	88	100	100	100
3	Pyroxasulfone	293	100	100	100	100	96
4	Indaziflam	52	100	100	100	100	100
5	Indaziflam	73	100	88	100	100	100
6	Pendimethalin	4,259	100	100	88	90	89
7	Pendimethalin	6,389	100	100	94	100	90
	Herbicide p-value		1	0.677	0.339	0.240	0.191

[1]Prostrate pigweed began to senesce approximately 150DAT-B.
[2]Analysis of herbicide main effects was done as randomized complete block design (RCBD) averaged over incorporation timing (N=8) to identify differences among herbicide treatments.
[3]DAT-B = days after treatment B

Appendix table 27. Overall weed control in a preemergence herbicide sequential application study in a fallow field in spring of 2021 (study 6) near Davis, CA.

No.	Treatment	Rate	Application Timing	DAT-A[1] 30	DAT-B 30	DAT-B 45	DAT-B 60
		g a.i. ha^{-1}		------------------% Control-----------------			
1	Indaziflam	52	A	88	92	90	88
	Pendimethalin	4,259	B				
2	Indaziflam	52	A	97	91	88	80
	Pendimethalin	6,389	B				
3	Indaziflam	52	A	87	95	93	88
	Pyroxasulfone	146	B				
4	Indaziflam	52	A	88	93	90	82
	Pyroxasulfone	293	B				
5	Pyroxasulfone	146	A	75	94	90	87
	Pendimethalin	4,259	B				
6	Pyroxasulfone	146	A	89	95	93	90
	Pendimethalin	6,389	B				
7	Pyroxasulfone	293	A	89	95	95	87
	Pendimethalin	4,259	B				
8	Pyroxasulfone	293	A	93	92	92	77
	Pendimethalin	6,389	B				
9	Penoxsulam +	29 +	A				
	Oxyfluorfen	1,379		94	92	87	80
	Pendimethalin	4,259	B				
10	Penoxsulam +	29 +	A				
	Oxyfluorfen	1,379		99	92	91	91
	Pendimethalin	6,389	B				
11	Flumioxazin	358	A	90	95	95	95
	Pendimethalin	4,259	B				
12	Flumioxazin	358	A	93	92	90	87
	Pendimethalin	6,389	B				
	P-value			0.095	0.787	0.500	0.637

[1]DAT-A = days after treatment A, DAT-B = days after treatment B

Appendix table 28. Control of redroot pigweed in a preemergence herbicide sequential application study in a fallow field in spring of 2021 (study 6) near Davis, CA.

No.	Treatment	Rate	Application Timing	DAT-B[1] 30	DAT-B[1] 45	DAT-B[1] 60
		g a.i. ha^{-1}		--------------% Control--------------		
1	Indaziflam	52	A	67	67	33
	Pendimethalin	4,259	B			
2	Indaziflam	52	A	100	67	67
	Pendimethalin	6,389	B			
3	Indaziflam	52	A	100	67	67
	Pyroxasulfone	146	B			
4	Indaziflam	52	A	100	100	100
	Pyroxasulfone	293	B			
5	Pyroxasulfone	146	A	100	100	67
	Pendimethalin	4,259	B			
6	Pyroxasulfone	146	A	100	67	100
	Pendimethalin	6,389	B			
7	Pyroxasulfone	293	A	100	100	100
	Pendimethalin	4,259	B			
8	Pyroxasulfone	293	A	100	100	100
	Pendimethalin	6,389	B			
9	Penoxsulam +	29 +	A			
	Oxyfluorfen	1,379		100	100	100
	Pendimethalin	4,259	B			
10	Penoxsulam +	29 +	A			
	Oxyfluorfen	1,379		100	100	100
	Pendimethalin	6,389	B			
11	Flumioxazin	358	A	100	100	100
	Pendimethalin	4,259	B			
12	Flumioxazin	358	A	100	67	67
	Pendimethalin	6,389	B			
	P-value			0.474	0.781	0.408

[1]DAT-B = days after treatment B

Appendix table 29. Control of malva in a preemergence herbicide sequential application study in a fallow field in spring of 2021 (study 6) near Davis, CA.

No.	Treatment	Rate	Application Timing	DAT-A[1] 30	DAT-B 30	DAT-B 45	DAT-B 60
		g a.i. ha^{-1}		% Control			
1	Indaziflam	52	A	100	100	100	100
	Pendimethalin	4,259	B				
2	Indaziflam	52	A	100	67	67	37
	Pendimethalin	6,389	B				
3	Indaziflam	52	A	100	100	67	67
	Pyroxasulfone	146	B				
4	Indaziflam	52	A	67	100	100	100
	Pyroxasulfone	293	B				
5	Pyroxasulfone	146	A	67	67	33	33
	Pendimethalin	4,259	B				
6	Pyroxasulfone	146	A	100	100	100	100
	Pendimethalin	6,389	B				
7	Pyroxasulfone	293	A	100	100	67	67
	Pendimethalin	4,259	B				
8	Pyroxasulfone	293	A	100	100	100	100
	Pendimethalin	6,389	B				
9	Penoxsulam +	29 +	A				
	Oxyfluorfen	1,379		100	100	100	100
	Pendimethalin	4,259	B				
10	Penoxsulam +	29 +	A				
	Oxyfluorfen	1,379		100	100	100	100
	Pendimethalin	6,389	B				
11	Flumioxazin	358	A	100	100	100	100
	Pendimethalin	4,259	B				
12	Flumioxazin	358	A	100	100	100	100
	Pendimethalin	6,389	B				
	P-value			0.547	0.623	0.263	0.096

[1]DAT-A = days after treatment A, DAT-B = days after treatment B

Appendix table 30. Control of field bindweed in a preemergence herbicide sequential application study in a fallow field in spring of 2021 (study 6) near Davis, CA.

No.	Treatment	Rate	Application Timing	DAT-A[1] 30	DAT-B 30	DAT-B 45	DAT-B 60
		g a.i. ha^{-1}		------------------% Control-----------------			
1	Indaziflam	52	A	0	33	23	0
	Pendimethalin	4,259	B				
2	Indaziflam	52	A	0	17	10	23
	Pendimethalin	6,389	B				
3	Indaziflam	52	A	33	43	17	23
	Pyroxasulfone	146	B				
4	Indaziflam	52	A	0	20	17	10
	Pyroxasulfone	293	B				
5	Pyroxasulfone	146	A	0	80	50	50
	Pendimethalin	4,259	B				
6	Pyroxasulfone	146	A	0	67	40	40
	Pendimethalin	6,389	B				
7	Pyroxasulfone	293	A	0	67	33	23
	Pendimethalin	4,259	B				
8	Pyroxasulfone	293	A	0	30	0	10
	Pendimethalin	6,389	B				
9	Penoxsulam +	29 +	A				
	Oxyfluorfen	1,379		33	0	0	0
	Pendimethalin	4,259	B				
10	Penoxsulam +	29 +	A				
	Oxyfluorfen	1,379		67	23	27	27
	Pendimethalin	6,389	B				
11	Flumioxazin	358	A	33	90	53	68
	Pendimethalin	4,259	B				
12	Flumioxazin	358	A	33	93	0	0
	Pendimethalin	6,389	B				
	P-value			0.559	0.370	0.484	0.252

[1]DAT-A = days after treatment A, DAT-B = days after treatment B

Appendix table 31. Control of filaree in a preemergence herbicide sequential application study in a fallow field in spring of 2021 (study 6) near Davis, CA.

No.	Treatment	Rate	Application Timing	DAT-A[1] 30	DAT-B 30	DAT-B 45	DAT-B 60
		g a.i. ha^{-1}		------------------% Control-----------------			
1	Indaziflam	52	A	100	100	100	100
	Pendimethalin	4,259	B				
2	Indaziflam	52	A	100	100	100	100
	Pendimethalin	6,389	B				
3	Indaziflam	52	A	100	100	67	67
	Pyroxasulfone	146	B				
4	Indaziflam	52	A	67	100	100	100
	Pyroxasulfone	293	B				
5	Pyroxasulfone	146	A	33	100	0	0
	Pendimethalin	4,259	B				
6	Pyroxasulfone	146	A	100	100	67	67
	Pendimethalin	6,389	B				
7	Pyroxasulfone	293	A	100	67	67	67
	Pendimethalin	4,259	B				
8	Pyroxasulfone	293	A	67	33	33	33
	Pendimethalin	6,389	B				
9	Penoxsulam +	29 +	A				
	Oxyfluorfen	1,379		100	100	67	67
	Pendimethalin	4,259	B				
10	Penoxsulam +	29 +	A				
	Oxyfluorfen	1,379		100	100	67	67
	Pendimethalin	6,389	B				
11	Flumioxazin	358	A	100	50	100	100
	Pendimethalin	4,259	B				
12	Flumioxazin	358	A	100	33	33	33
	Pendimethalin	6,389	B				
	P-value			0.135	0.135	0.175	0.175

[1]DAT-A = days after treatment A, DAT-B = days after treatment B

Appendix table 32. Overall weed control in a preemergence sequential application study in a 2-yr-old almond orchard in spring of 2022 (study 7) near Arbuckle, CA.

No.	Treatment	Rate	Application timing	DAT-A[1]		DAT-B[2]					
				30	45	30	45	60	75	90	105
		g a.i. ha^{-1}		% Control							
1	Indaziflam	52	A	97	96	90	90	84	70	68	55
	Pendimethalin	4,259	B								
2	Indaziflam	52	A	100	98	92	90	88	80	72	62
	Pendimethalin	6,389	B								
3	Indaziflam	52	A	96	96	93	90	85	72	68	37
	Pyroxasulfone	293	B								
4	Indaziflam	52	A	99	98	93	93	87	71	62	50
	Pyroxasulfone	293	B								
5	Pyroxasulfone	146	A	99	97	93	90	87	76	52	42
	Pendimethalin	4,259	B								
6	Pyroxasulfone	146	A	99	97	88	88	87	75	62	53
	Pendimethalin	6,389	B								
7	Pyroxasulfone	293	A	96	97	95	94	95	81	82	75
	Pendimethalin	4,259	B								
8	Pyroxasulfone	293	A	100	98	98	95	93	86	82	70
	Pendimethalin	6,389	B								
9	Penoxsulam +	29 +	A	98	99	93	92	88	76	70	48
	Oxyfluron	1,379									
	Pendimethalin	4,259	B								
10	Penoxsulam +	25 +	A	99	99	93	94	91	81	73	52
	Oxyfluron	1,379									
	Pendimethalin	6,389	B								
11	Flumioxazin	358	A	98	98	90	90	87	76	70	58
	Pendimethalin	4,259	B								
12	Flumioxazin	356	A	97	98	97	96	90	85	82	67
	Pendimethalin	6,389	B								
	P-value			0.185	0.275	0.325	0.583	0.893	0.941	0.732	0.546

[1]DAT-A = days after treatment A, DAT-B = days after treatment B

Appendix table 33. Control of field bindweed in a preemergence sequential application study in a 2-yr-old almond orchard in spring of 2022 (study 7) near Arbuckle, CA.

No.	Treatment	Rate	Application timing	DAT-B[1] 30	45	60	75	90	105
		g a.i. ha^{-1}		--------------------------------% Control---------------------------					
1	Indaziflam	52	A	67	33	67	0	0	0
	Pendimethalin	4,259	B						
2	Indaziflam	52	A	33	33	33	0	0	0
	Pendimethalin	6,389	B						
3	Indaziflam	52	A	100	16	17	0	0	0
	Pyroxasulfone	146	B						
4	Indaziflam	52	A	100	67	33	0	0	0
	Pyroxasulfone	293	B						
5	Pyroxasulfone	146	A	100	33	33	0	0	0
	Pendimethalin	4,259	B						
6	Pyroxasulfone	146	A	67	67	67	33	33	33
	Pendimethalin	6,389	B						
7	Pyroxasulfone	293	A	67	33	33	0	33	0
	Pendimethalin	4,259	B						
8	Pyroxasulfone	293	A	100	67	67	23	0	0
	Pendimethalin	6,389	B						
9	Penoxsulam +	29 +	A						
	Oxyfluron	1,379		33	33	33	0	0	0
	Pendimethalin	4,259	B						
10	Penoxsulam +	29 +	A						
	Oxyfluron	1,379		67	33	33	0	33	33
	Pendimethalin	6,389	B						
11	Flumioxazin	358	A	100	100	93	67	33	0
	Pendimethalin	4,259	B						
12	Flumioxazin	358	A	67	67	0	3	33	0
	Pendimethalin	6,389	B						
	P-value			0.494	0.802	0.663	0.172	0.781	0.704

[1]DAT-B = days after treatment B

Appendix table 34. Control of hairy fleabane in a preemergence sequential application study in a 2-yr-old almond orchard in spring of 2022 (study 7) near Arbuckle, CA.

No.	Treatment	Rate	Application timing	DAT-B[1] 30	45	60	75	90	105
		g a.i. ha^{-1}		--------------------------------% Control---------------------------					
1	Indaziflam	52	A	68	33	33	27	26	25
	Pendimethalin	4,259	B						
2	Indaziflam	52	A	100	100	100	67	100	67
	Pendimethalin	6,389	B						
3	Indaziflam	52	A	100	100	83	67	40	33
	Pyroxasulfone	146	B						
4	Indaziflam	52	A	100	100	100	67	33	33
	Pyroxasulfone	293	B						
5	Pyroxasulfone	146	A	33	0	0	0	0	0
	Pendimethalin	4,259	B						
6	Pyroxasulfone	146	A	100	100	100	67	67	33
	Pendimethalin	6,389	B						
7	Pyroxasulfone	293	A	33	7	0	17	17	17
	Pendimethalin	4,259	B						
8	Pyroxasulfone	293	A	100	100	100	100	100	100
	Pendimethalin	6,389	B						
9	Penoxsulam +	29 +	A	33	33	50	0	0	0
	Oxyfluron	1,379							
	Pendimethalin	4,259	B						
10	Penoxsulam +	29 +	A	100	100	100	100	100	100
	Oxyfluron	1,379							
	Pendimethalin	6,389	B						
11	Flumioxazin	358	A	33	33	33	33	0	0
	Pendimethalin	4,259	B						
12	Flumioxazin	358	A	100	100	100	100	100	100
	Pendimethalin	6,389	B						
	P-value			0.213	0.153	0.565	0.686	0.513	0.707

[1]DAT-B = days after treatment B

Appendix table 35. Control of crabgrass in a preemergence sequential application study in a 2-yr-old almond orchard in spring of 2022 (study 7) near Arbuckle, CA.

No.	Treatment	Rate	Application timing	DAT-B[1]	
				90	105
		g a.i. ha^{-1}		--% Control--	
1	Indaziflam	52	A	100	0
	Pendimethalin	4,259	B		
2	Indaziflam	52	A	100	67
	Pendimethalin	6,389	B		
3	Indaziflam	52	A	100	100
	Pyroxasulfone	146	B		
4	Indaziflam	52	A	33	33
	Pyroxasulfone	293	B		
5	Pyroxasulfone	146	A	100	67
	Pendimethalin	4,259	B		
6	Pyroxasulfone	146	A	67	33
	Pendimethalin	6,389	B		
7	Pyroxasulfone	293	A	100	0
	Pendimethalin	4,259	B		
8	Pyroxasulfone	293	A	100	100
	Pendimethalin	6,389	B		
9	Penoxsulam +	29 +	A		
	Oxyfluron	1,379		100	0
	Pendimethalin	4,259	B		
10	Penoxsulam +	29 +	A		
	Oxyfluron	1,379		100	100
	Pendimethalin	6,389	B		
11	Flumioxazin	358	A	100	67
	Pendimethalin	4,259	B		
12	Flumioxazin	358	A	100	100
	Pendimethalin	6,389	B		
	P-value			0.624	0.134

[1]DAT-B = days after treatment B

Appendix table 36. Control of spotted spurge in a preemergence sequential application study in a 2-yr-old almond orchard in spring of 2022 (study 7) near Arbuckle, CA.

No.	Treatment	Rate	Application timing	DAT-B[1]	
				90	105
		g a.i. ha^{-1}		--% Control--	
1	Indaziflam	52	A	67	20
	Pendimethalin	4,259	B		
2	Indaziflam	52	A	67	56
	Pendimethalin	6,389	B		
3	Indaziflam	52	A	33	0
	Pyroxasulfone	146	B		
4	Indaziflam	52	A	67	20
	Pyroxasulfone	293	B		
5	Pyroxasulfone	146	A	67	33
	Pendimethalin	4,259	B		
6	Pyroxasulfone	146	A	67	33
	Pendimethalin	6,389	B		
7	Pyroxasulfone	293	A	67	23
	Pendimethalin	4,259	B		
8	Pyroxasulfone	293	A	67	67
	Pendimethalin	6,389	B		
9	Penoxsulam +	29 +	A	67	67
	Oxyfluron	1,379			
	Pendimethalin	4,259	B		
10	Penoxsulam +	29 +	A	100	67
	Oxyfluron	1,379			
	Pendimethalin	6,389	B		
11	Flumioxazin	358	A	100	25
	Pendimethalin	4,259	B		
12	Flumioxazin	358	A	100	67
	Pendimethalin	6,389	B		
	P-value			0.827	0.745

[1]DAT-B = days after treatment B

Appendix table 37. Control of malva in a preemergence sequential application study in a 2-yr-old almond orchard in spring of 2022 (study 7) near Arbuckle, CA.

No.	Treatment	Rate	Application timing	DAT-B[1] 30	45	60	75	90	105
		g a.i. ha^{-1}		--% Control--					
1	Indaziflam	52	A	100	100	100	67	67	67
	Pendimethalin	4,259	B						
2	Indaziflam	52	A	100	100	100	100	100	100
	Pendimethalin	6,389	B						
3	Indaziflam	52	A	100	100	100	100	100	67
	Pyroxasulfone	146	B						
4	Indaziflam	52	A	100	100	100	100	100	100
	Pyroxasulfone	293	B						
5	Pyroxasulfone	146	A	100	100	100	100	100	67
	Pendimethalin	4,259	B						
6	Pyroxasulfone	146	A	100	100	100	100	100	67
	Pendimethalin	6,389	B						
7	Pyroxasulfone	293	A	100	100	100	100	100	100
	Pendimethalin	4,259	B						
8	Pyroxasulfone	293	A	100	100	100	100	100	100
	Pendimethalin	6,389	B						
9	Penoxsulam +	29 +	A						100
	Oxyfluron	1,379		100	100	100	100	100	
	Pendimethalin	4,259	B						
10	Penoxsulam +	29 +	A						
	Oxyfluron	1,379		100	100	100	100	100	100
	Pendimethalin	6,389	B						
11	Flumioxazin	358	A	100	100	100	67	67	67
	Pendimethalin	4,259	B						
12	Flumioxazin	358	A	100	100	100	67	67	67
	Pendimethalin	6,389	B						
	P-value			1	1	1	0.623	0.624	0.781

[1]DAT-B = days after treatment B

Appendix table 38. Control of annual sowthistle in a preemergence sequential application study in a 2-yr-old almond orchard in spring of 2022 (study 7) near Arbuckle, CA.

No.	Treatment	Rate	Application timing	DAT-B[1] 30	45	60	75	90	105
		g a.i. ha^{-1}		---% Control---					
1	Indaziflam	52	A	100	100	100	67	67	33
	Pendimethalin	4,259	B						
2	Indaziflam	52	A	100	100	100	67	100	67
	Pendimethalin	6,389	B						
3	Indaziflam	52	A	100	100	100	67	67	67
	Pyroxasulfone	146	B						
4	Indaziflam	52	A	100	100	100	67	33	33
	Pyroxasulfone	293	B						
5	Pyroxasulfone	146	A	100	100	100	67	67	67
	Pendimethalin	4,259	B						
6	Pyroxasulfone	146	A	100	100	100	67	67	33
	Pendimethalin	6,389	B						
7	Pyroxasulfone	293	A	100	100	100	67	67	67
	Pendimethalin	4,259	B						
8	Pyroxasulfone	293	A	100	100	100	100	100	100
	Pendimethalin	6,389	B						
9	Penoxsulam +	29 +	A						
	Oxyfluron	1,379		100	100	100	100	100	100
	Pendimethalin	4,259	B						
10	Penoxsulam +	29 +	A						
	Oxyfluron	1,379		100	100	100	100	100	100
	Pendimethalin	6,389	B						
11	Flumioxazin	358	A	100	100	100	100	67	67
	Pendimethalin	4,259	B						
12	Flumioxazin	358	A	100	100	100	100	100	100
	Pendimethalin	6,389	B						
	P-value			1	1	1	0.913	0.827	0.512

[1]DAT-B = days after treatment B

Appendix table 39. Overall weed control in a 2-yr-old almond orchard using a single application of preemergence herbicides near Arbuckle CA in spring 2022 (study 8).

No.	Treatment	Rate	DAT[1]				
			30	45	60	75	90[2]
		g a.i. ha^{-1}	% Control				
1	Indaziflam	29	98	98	90	83	68
	Glufosinate	984					
2	Indaziflam	39	99	99	92	73	68
	Glufosinate	1,334					
3	Indaziflam	49	100	100	91	77	68
	Glufosinate	1,704					
4	Indaziflam	73	99	99	91	78	68
	Glufosinate	1,334					
5	Pyroxasulfone	219	100	100	84	73	55
	Glufosinate	1,704					
6	Pyroxasulfone	293	99	99	85	78	70
	Glufosinate	1,704					
7	Pendimethalin	4,259	98	98	94	78	68
	Glufosinate	1,704					
8	Pendimethalin	6,389	99	99	86	83	73
	Glufosinate	1,704					
	P-value		0.678	0.678	0.415	0.802	0.893

[1]DAT = days after treatment

[2]90 DAT (N=2); replication 3 was over sprayed with contact herbicide during orchard maintenance.

Appendix table 40. Control of common knotweed in a 2-yr-old almond orchard using a single application of preemergence herbicides near Arbuckle, CA in spring 2022 (study 8).

No.	Treatment	Rate	DAT[1]		
			60	75	90[2]
		g a.i. ha^{-1}	% Control		
1	Indaziflam Glufosinate	29 984	50	40 ab	35 ab
2	Indaziflam Glufosinate	39 1,334	22	33 b	0 b
3	Indaziflam Glufosinate	49 1,704	67	53 ab	15 b
4	Indaziflam Glufosinate	73 1,334	33	33 b	100 a
5	Pyroxasulfone Glufosinate	219 1,704	33	0 b	0 b
6	Pyroxasulfone Glufosinate	293 1,704	33	46 ab	50 ab
7	Pendimethalin Glufosinate	4,259 1,704	100	100 a	100 a
8	Pendimethalin Glufosinate	6,389 1,704	100	100 a	100 a
	P-value		0.412	0.056	0.034

[1]DAT = days after treatment
[2]90 DAT (N=2); replication 3 was over sprayed with contact herbicide during orchard maintenance.

Appendix table 41. Control of field bindweed in a 2-yr-old almond orchard using a single application of preemergence herbicides near Arbuckle, CA in spring 2022 (study 8).

No.	Treatment	Rate	DAT[1]		
			60	75	90[2]
		g a.i. ha^{-1}	% Control		
1	Indaziflam Glufosinate	29 984	67	23	75
2	Indaziflam Glufosinate	39 1,334	67	0	0
3	Indaziflam Glufosinate	49 1,704	0	13	0
4	Indaziflam Glufosinate	73 1,334	63	0	50
5	Pyroxasulfone Glufosinate	219 1,704	33	33	0
6	Pyroxasulfone Glufosinate	293 1,704	0	0	0
7	Pendimethalin Glufosinate	4,259 1,704	67	67	50
8	Pendimethalin Glufosinate	6,389 1,704	33	23	0
	P-value		0.412	0.056	0.034

[1]DAT = days after treatment

[2]90 DAT (N=2); replication 3 was over sprayed with contact herbicide during orchard maintenance.

Appendix table 42. Control of filaree in a 2-yr-old almond orchard using a single application of preemergence herbicides near Arbuckle, CA in spring 2022 (study 8).

No.	Treatment	Rate	DAT[1]		
			60	75	90[2]
		g a.i. ha^{-1}	% Control		
1	Indaziflam	29	0	0	63
	Glufosinate	984			
2	Indaziflam	39	67	67	100
	Glufosinate	1,334			
3	Indaziflam	49	67	67	50
	Glufosinate	1,704			
4	Indaziflam	73	100	100	50
	Glufosinate	1,334			
5	Pyroxasulfone	219	67	33	100
	Glufosinate	1,704			
6	Pyroxasulfone	293	67	67	100
	Glufosinate	1,704			
7	Pendimethalin	4,259	100	100	100
	Glufosinate	1,704			
8	Pendimethalin	6,389	100	100	100
	Glufosinate	1,704			
	P-value		0.125	0.125	0.660

[1]DAT = days after treatment
[2]90 DAT (N=2); replication 3 was over sprayed with contact herbicide during orchard maintenance.

Appendix table 43. Control of Italian ryegrass in a 2-yr-old almond orchard using a single application of preemergence herbicides near Arbuckle, CA in spring 2022 (study 8).

No.	Treatment	Rate	DAT[1]		
			60	75	90[2]
		g a.i. ha^{-1}	% Control		
1	Indaziflam Glufosinate	29 984	90	67	85
2	Indaziflam Glufosinate	39 1,334	67	67	100
3	Indaziflam Glufosinate	49 1,704	100	100	100
4	Indaziflam Glufosinate	73 1,334	33	33	100
5	Pyroxasulfone Glufosinate	219 1,704	33	40	100
6	Pyroxasulfone Glufosinate	293 1,704	100	100	100
7	Pendimethalin Glufosinate	4,259 1,704	100	67	100
8	Pendimethalin Glufosinate	6,389 1,704	57	60	100
	P-value		0.214	0.642	0.493

[1]DAT = days after treatment
[2]90 DAT (N=2); replication 3 was over sprayed with contact herbicide during orchard maintenance.

Appendix table 44. Control of annual sowthistle in a 2-yr-old almond orchard using a single application of preemergence herbicides near Arbuckle, CA in spring 2022 (study 8).

No.	Treatment	Rate	DAT[1]		
			60	75	90[2]
		g a.i. ha^{-1}	% Control		
1	Indaziflam Glufosinate	29 984	33	33	35
2	Indaziflam Glufosinate	39 1,334	17	23	0
3	Indaziflam Glufosinate	49 1,704	50	50	50
4	Indaziflam Glufosinate	73 1,334	33	33	50
5	Pyroxasulfone Glufosinate	219 1,704	0	7	0
6	Pyroxasulfone Glufosinate	293 1,704	33	40	25
7	Pendimethalin Glufosinate	4,259 1,704	33	30	50
8	Pendimethalin Glufosinate	6,389 1,704	50	50	0
	P-value		0.923	0.946	0.833

[1]DAT = days after treatment

[2]90 DAT (N=2); replication 3 was over sprayed with contact herbicide during orchard maintenance.

Appendix table 45. Overall weed control in a walnut orchard study using preemergence herbicides near Davis, CA in spring 2022 (study 9).

No.	Treatment	Rate	DAT[1]			
			30	45	60	75
		g a.i. ha^{-1}	% Control			
1	Indaziflam Glufosinate	29 984	84	72	50	51
2	Indaziflam Glufosinate	39 1,334	88	87	70	71
3	Indaziflam Glufosinate	49 1,704	88	89	82	84
4	Indaziflam Glufosinate	73 1,334	88	85	63	61
5	Pyroxasulfone Glufosinate	219 1,704	83	78	51	60
6	Pyroxasulfone Glufosinate	293 1,704	83	89	81	74
7	Pendimethalin Glufosinate	4,259 1,704	87	87	73	61
8	Pendimethalin Glufosinate	6,389 1,704	85	82	63	63
	P-value		0.975	0.664	0.670	0.901

[1]DAT = days after treatment

Appendix table 46. Control of bermudagrass in a walnut orchard study using preemergence herbicides near Davis, CA in spring 2022 (study 9).

No.	Treatment	Rate	DAT[1]			
			30	45	60	75
		g a.i. ha^{-1}	--------------------------% Control--------------------------			
1	Indaziflam	29	75	75	25	25
	Glufosinate	984				
2	Indaziflam	39	70	75	25	25
	Glufosinate	1,334				
3	Indaziflam	49	73	50	25	25
	Glufosinate	1,704				
4	Indaziflam	73	75	75	50	48
	Glufosinate	1,334				
5	Pyroxasulfone	219	60	75	25	25
	Glufosinate	1,704				
6	Pyroxasulfone	293	48	50	25	25
	Glufosinate	1,704				
7	Pendimethalin	4,259	70	25	25	25
	Glufosinate	1,704				
8	Pendimethalin	6,389	95	25	25	25
	Glufosinate	1,704				
	P-value		0.921	0.652	0.996	0.998

[1]DAT = days after treatment

Appendix table 47. Control of malva in a walnut orchard study using preemergence herbicides near Davis, CA in spring 2022 (study 9).

No.	Treatment	Rate	DAT[1]			
			30	45	60	75
		g a.i. ha^{-1}	-------------------------% Control-------------------------			
1	Indaziflam	29	100	100	100	100
	Glufosinate	984				
2	Indaziflam	39	75	75	50	50
	Glufosinate	1,334				
3	Indaziflam	49	75	75	75	75
	Glufosinate	1,704				
4	Indaziflam	73	100	75	75	50
	Glufosinate	1,334				
5	Pyroxasulfone	219	50	50	50	50
	Glufosinate	1,704				
6	Pyroxasulfone	293	75	75	75	75
	Glufosinate	1,704				
7	Pendimethalin	4,259	75	75	75	50
	Glufosinate	1,704				
8	Pendimethalin	6,389	75	75	75	75
	Glufosinate	1,704				
	P-value		0.811	0.942	0.625	0.802

[1]DAT = days after treatment

Appendix table 48. Control of foxtail barley in a walnut orchard study using preemergence herbicides near Davis, CA in spring 2022 (study 9).

No.	Treatment	Rate	DAT[1]		
			45	60	75
		g a.i. ha^{-1}	-------------------% Control----------------		
1	Indaziflam	29	100	100	100
	Glufosinate	984			
2	Indaziflam	39	75	50	50
	Glufosinate	1,334			
3	Indaziflam	49	75	75	75
	Glufosinate	1,704			
4	Indaziflam	73	75	75	50
	Glufosinate	1,334			
5	Pyroxasulfone	219	50	50	50
	Glufosinate	1,704			
6	Pyroxasulfone	293	75	75	75
	Glufosinate	1,704			
7	Pendimethalin	4,259	75	75	50
	Glufosinate	1,704			
8	Pendimethalin	6,389	75	75	75
	Glufosinate	1,704			
	P-value		0.942	0.625	0.802

[1]DAT = days after treatment

Appendix table 49. Control of filaree in a walnut orchard study using preemergence herbicides near Davis, CA in spring 2022 (study 9).

No.	Treatment	Rate	DAT[1]			
			30	45	60	75
		g a.i. ha^{-1}	--------------------------% Control--------------------------			
1	Indaziflam	29	100	100	100	100
	Glufosinate	984				
2	Indaziflam	39	100	100	100	100
	Glufosinate	1,334				
3	Indaziflam	49	75	75	75	75
	Glufosinate	1,704				
4	Indaziflam	73	75	75	75	75
	Glufosinate	1,334				
5	Pyroxasulfone	219	50	50	50	50
	Glufosinate	1,704				
6	Pyroxasulfone	293	75	75	75	75
	Glufosinate	1,704				
7	Pendimethalin	4,259	75	75	75	75
	Glufosinate	1,704				
8	Pendimethalin	6,389	75	75	75	75
	Glufosinate	1,704				
	P-value		0.811	0.683	0.811	0.811

[1]DAT = days after treatment

Appendix table 50. Control of California burclover in a walnut orchard study using preemergence herbicides near Davis, CA in spring 2022 (study 9).

No.	Treatment	Rate	DAT[1]			
			30	45	60	75
		g a.i. ha^{-1}	--------------------------% Control--------------------------			
1	Indaziflam	29	75	100	100	100
	Glufosinate	984				
2	Indaziflam	39	100	100	50	50
	Glufosinate	1,334				
3	Indaziflam	49	100	100	100	100
	Glufosinate	1,704				
4	Indaziflam	73	100	100	100	75
	Glufosinate	1,334				
5	Pyroxasulfone	219	100	100	75	75
	Glufosinate	1,704				
6	Pyroxasulfone	293	75	75	75	75
	Glufosinate	1,704				
7	Pendimethalin	4,259	100	100	100	100
	Glufosinate	1,704				
8	Pendimethalin	6,389	100	100	100	75
	Glufosinate	1,704				
	P-value		0.553	0.455	0.262	0.901

[1]DAT = days after treatment

Appendix table 51. Overall weed control with preemergence herbicides in an almond orchard study in spring 2021 near Davis, CA (study 10).

No.	Treatment	Rate	DAT[1]						
			30	45	60	75	90	120	150
		g a.i. ha^{-1}	% Control						
1	Indaziflam	56	93	87	93	88	82	85	88
2	Rimsulfuron	70	88	92	92	95	85	92	90
3	Flumioxazin	882	93	90	94	93	82	87	83
4	Pendimethalin	4,259	100	92	95	96	84	93	96
5	Pyroxasulfone	150	100	93	99	93	86	92	93
6	Pyroxasulfone	225	100	95	94	93	96	88	63
7	Pyroxasulfone	300	98	97	94	95	84	89	91
8	Pyroxasulfone Pendimethalin	150 4,259	98	100	96	95	84	90	87
9	Pyroxasulfone Pendimethalin	225 4,259	63	100	99	96	85	96	88
10	Flumioxazin + Pyroxasulfone	118 150	92	100	98	96	85	93	93
11	Flumioxazin + Pyroxasulfone	178 225	100	70	99	99	87	96	93
12	Pyroxasulfone Rimsulfuron	150 70	100	93	94	94	84	92	91
13	Pyroxasulfone Rimsulfuron	225 70	87	100	98	94	97	90	62
14	Oxyfluorfen Pendimethalin	2,018 4,259	97	99	99	96	84	85	88
	P-value		0.511	0.623	0.512	0.712	0.998	0.672	0.634

[1]DAT = days after treatment

Appendix table 52. Control of ryegrass with preemergence herbicides in an almond orchard study in spring 2021 near Davis, CA (study 10).

No.	Treatment	Rate	DAT[1]					
			30	45	60	75	90	120
		g a.i. ha^{-1}	% Control					
1	Indaziflam	56	93	87	93	88	82	85
2	Rimsulfuron	70	88	92	92	95	85	92
3	Flumioxazin	882	93	90	94	93	82	87
4	Pendimethalin	4,259	100	92	95	96	84	93
5	Pyroxasulfone	150	100	93	99	93	86	92
6	Pyroxasulfone	225	100	95	94	93	96	88
7	Pyroxasulfone	300	98	97	94	95	84	89
8	Pyroxasulfone Pendimethalin	150 4,259	98	100	96	95	84	90
9	Pyroxasulfone Pendimethalin	225 4,259	63	100	99	96	85	96
10	Flumioxazin + Pyroxasulfone	118 150	92	100	98	96	85	93
11	Flumioxazin + Pyroxasulfone	178 225	100	70	99	99	87	96
12	Pyroxasulfone Rimsulfuron	150 70	100	93	94	94	84	92
13	Pyroxasulfone Rimsulfuron	225 70	87	100	98	94	97	90
14	Oxyfluorfen Pendimethalin	2,018 4,259	97	99	99	96	84	85
	P-value		0.511	0.623	0.512	0.712	0.998	0.672

[1]DAT = days after treatment

Appendix table 53. Control field bindweed with preemergence herbicides in an almond orchard study in spring 2021 near Davis, CA (study 10).

No.	Treatment	Rate	DAT[1]						
			30	45	60	75	90	120	150
		g a.i. ha^{-1}	% Control						
1	Indaziflam	56	47	47	100	70	67	57	47
2	Rimsulfuron	70	50	17	83	40	93	33	50
3	Flumioxazin	882	57	53	70	40	33	27	57
4	Pendimethalin	4,259	100	80	67	63	100	90	100
5	Pyroxasulfone	150	72	93	50	57	90	70	72
6	Pyroxasulfone	225	67	30	40	23	93	50	67
7	Pyroxasulfone	300	67	57	33	23	90	60	67
8	Pyroxasulfone Pendimethalin	150 4,259	90	83	43	33	100	23	90
9	Pyroxasulfone Pendimethalin	225 4,259	100	100	73	70	100	33	100
10	Flumioxazin + Pyroxasulfone	118 150	100	87	73	49	60	70	100
11	Flumioxazin + Pyroxasulfone	178 225	100	63	100	80	100	75	100
12	Pyroxasulfone Rimsulfuron	150 70	67	80	77	17	77	50	67
13	Pyroxasulfone Rimsulfuron	225 70	100	80	67	40	100	57	100
14	Oxyfluorfen Pendimethalin	2,018 4,259	93	87	63	17	100	50	93
	P-value		0.340	0.141	0.428	0.363	0.166	0.829	0.340

[1]DAT = days after treatment

Appendix table 54. Overall weed control with preemergence herbicides in an almond orchard study in spring 2021 near Winters, CA (study 11).

No.	Treatment	Rate	DAT[1]				
			30	45	75	90	120
		g a.i. ha^{-1}	---% Control---				
1	Indaziflam	56	89 c	86	96	96	88
2	Rimsulfuron	70	95 ab	86	98	97	86
3	Flumioxazin	882	97 a	95	98	97	96
4	Pendimethalin	4,259	93 abc	86	97	97	96
5	Pyroxasulfone	150	90 abc	85	98	98	94
6	Pyroxasulfone	225	96 a	85	99	97	93
7	Pyroxasulfone	300	93 abc	86	98	97	91
8	Pyroxasulfone Pendimethalin	150 4,259	92 abc	91	99	97	73
9	Pyroxasulfone Pendimethalin	225 4,259	96 a	90	97	95	94
10	Flumioxazin + Pyroxasulfone	118 150	97 a	71	97	97	94
11	Flumioxazin + Pyroxasulfone	178 225	96 a	94	99	98	91
12	Pyroxasulfone Rimsulfuron	150 70	96 a	93	98	97	93
13	Pyroxasulfone Rimsulfuron	225 70	93 abc	93	98	98	93
14	Oxyfluorfen Pendimethalin	2,018 4,259	95 ab	95	98	96	93
	P-value		0.058	0.732	0.800	0.986	0.598

[1]DAT = days after treatment

Appendix table 55. Control field bindweed with preemergence herbicides in an almond orchard study in spring 2021 near Winters, CA (study 11).

No.	Treatment	Rate	DAT[1]		
			75	90	120
		g a.i. ha^{-1}	---------------% Control-----------------		
1	Indaziflam	56	96	96	88
2	Rimsulfuron	70	98	97	86
3	Flumioxazin	882	98	97	96
4	Pendimethalin	4,259	97	97	96
5	Pyroxasulfone	150	98	98	94
6	Pyroxasulfone	225	99	97	93
7	Pyroxasulfone	300	98	97	91
8	Pyroxasulfone Pendimethalin	150 4,259	99	97	73
9	Pyroxasulfone Pendimethalin	225 4,259	97	95	94
10	Flumioxazin + Pyroxasulfone	118 150	97	97	94
11	Flumioxazin + Pyroxasulfone	178 225	99	98	91
12	Pyroxasulfone Rimsulfuron	150 70	98	97	93
13	Pyroxasulfone Rimsulfuron	225 70	98	98	93
14	Oxyfluorfen Pendimethalin	2,018 4,259	98	96	93
	P-value		0.800	0.986	0.598

[1]DAT = days after treatment

Appendix table 56. Control of prostrate knotweed with preemergence herbicides in an almond orchard study in spring 2021 near Winters, CA (study 6).

No.	Treatment	Rate	DAT[1]			
			75		90	120
		g a.i. ha^{-1}	----------------% Control-----------------			
1	Indaziflam	56	100	a	50	50
2	Rimsulfuron	70	75	ab	75	50
3	Flumioxazin	882	75	ab	50	50
4	Pendimethalin	4,259	100	a	75	75
5	Pyroxasulfone	150	100	a	100	75
6	Pyroxasulfone	225	100	a	100	100
7	Pyroxasulfone	300	100	a	95	75
8	Pyroxasulfone Pendimethalin	150 4,259	100	a	100	100
9	Pyroxasulfone Pendimethalin	225 4,259	0	c	75	100
10	Flumioxazin + Pyroxasulfone	118 150	75	ab	100	100
11	Flumioxazin + Pyroxasulfone	178 225	75	ab	75	100
12	Pyroxasulfone Rimsulfuron	150 70	100	a	63	100
13	Pyroxasulfone Rimsulfuron	225 70	78	ab	75	75
14	Oxyfluorfen Pendimethalin	2,018 4,259	50	b	75	93
	P-value		0.005		0.725	0.360

[1]DAT = days after treatment

Appendix table 57. Control of prostrate pigweed with preemergence herbicides in an almond orchard study in spring 2021 near Winters, CA (study 11).

No.	Treatment	Rate	120 DAT
		g a.i. ha^{-1}	% Control
1	Indaziflam	56	50 bc
2	Rimsulfuron	70	25 c
3	Flumioxazin	882	100 a
4	Pendimethalin	4,259	100 a
5	Pyroxasulfone	150	75 ab
6	Pyroxasulfone	225	50 bc
7	Pyroxasulfone	300	75 ab
8	Pyroxasulfone Pendimethalin	150 4,259	100 a
9	Pyroxasulfone Pendimethalin	225 4,259	100 a
10	Flumioxazin + Pyroxasulfone	118 150	100 a
11	Flumioxazin + Pyroxasulfone	178 225	100 a
12	Pyroxasulfone Rimsulfuron	150 70	100 a
13	Pyroxasulfone Rimsulfuron	225 70	100 a
14	Oxyfluorfen Pendimethalin	2,018 4,259	93 a
	P-value		0.016

[1]DAT = days after treatment

Appendix table 58. Control of malva with preemergence herbicides in an almond orchard study in spring 2021 near Winters CA (study 11).

No.	Treatment	Rate	DAT[1] 75	DAT[1] 90	DAT[1] 120	
		g a.i. ha^{-1}	-------------------% Control---------------------			
1	Indaziflam	56	50	63	50	bc
2	Rimsulfuron	70	50	93	25	c
3	Flumioxazin	882	75	100	100	a
4	Pendimethalin	4,259	50	100	100	a
5	Pyroxasulfone	150	50	93	75	ab
6	Pyroxasulfone	225	67	68	50	bc
7	Pyroxasulfone	300	25	93	75	ab
8	Pyroxasulfone Pendimethalin	150 4,259	100	100	100	a
9	Pyroxasulfone Pendimethalin	225 4,259	100	100	100	a
10	Flumioxazin + Pyroxasulfone	118 150	100	100	100	a
11	Flumioxazin + Pyroxasulfone	178 225	100	100	100	a
12	Pyroxasulfone Rimsulfuron	150 70	50	68	100	a
13	Pyroxasulfone Rimsulfuron	225 70	50	100	100	a
14	Oxyfluorfen Pendimethalin	2,018 4,259	100	100	93	a
	P-value		0.209	0.160	0.016	

[1]DAT = days after treatment

Appendix table 59. Overall weed control with preemergence herbicides in a vineyard study in spring 2021 near Davis, CA (study 12).

No.	Treatment	Rate	DAT[1]						
			30	45	60	75	90	120	150
		g a.i. ha^{-1}	% Control						
1	Indaziflam	56	100	100	98	97	95	96	95
2	Rimsulfuron	70	100	100	72	98	97	99	94
3	Flumioxazin	882	100	100	94	97	98	98	96
4	Pendimethalin	4,259	100	100	97	96	97	97	96
5	Pyroxasulfone	150	100	100	95	97	99	99	98
6	Pyroxasulfone	225	100	100	98	97	99	99	98
7	Pyroxasulfone	300	100	100	95	95	98	98	96
8	Pyroxasulfone Pendimethalin	150 4,259	100	100	97	98	98	98	96
9	Pyroxasulfone Pendimethalin	225 4,259	100	100	96	96	98	96	93
10	Flumioxazin + Pyroxasulfone	118 150	100	100	97	99	98	99	97
11	Flumioxazin + Pyroxasulfone	178 225	100	100	96	97	98	98	96
12	Pyroxasulfone Rimsulfuron	150 70	100	100	94	97	98	99	94
13	Pyroxasulfone Rimsulfuron	225 70	100	100	96	99	98	99	96
14	Oxyfluorfen Pendimethalin	2,018 4,259	100	100	96	98	99	98	98
	P-value		0.482	0.966	0.823	0.937	0.084	0.482	0.966

[1]DAT = days after treatment

Appendix table 60. Control of filaree[1] with preemergence herbicides in a vineyard study in spring 2021 near Davis, CA (study 12).

No.	Treatment	Rate	DAT[2]		
			60	75	90
		g a.i. ha^{-1}	-----------------% Control-----------------		
1	Indaziflam	56	100	100	100
2	Rimsulfuron	70	25	100	100
3	Flumioxazin	882	50	75	100
4	Pendimethalin	4,259	0	75	75
5	Pyroxasulfone	150	75	75	75
6	Pyroxasulfone	225	75	75	100
7	Pyroxasulfone	300	25	75	75
8	Pyroxasulfone Pendimethalin	150 4,259	67	67	100
9	Pyroxasulfone Pendimethalin	225 4,259	50	100	100
10	Flumioxazin + Pyroxasulfone	118 150	75	100	100
11	Flumioxazin + Pyroxasulfone	178 225	50	75	100
12	Pyroxasulfone Rimsulfuron	150 70	25	100	75
13	Pyroxasulfone Rimsulfuron	225 70	50	75	100
14	Oxyfluorfen Pendimethalin	2,018 4,259	100	100	100
	P-value		0.590	0.830	0.910

[1]Filaree began to senesce approximately 90DAT
[2]DAT = days after treatment

Appendix table 61. Control of hare barley[1] with preemergence herbicides in a vineyard study in spring 2021 near Davis, CA (study 12).

No.	Treatment	Rate	DAT[2] 75	DAT[2] 90
		g a.i. ha^{-1}	---------% Control--------	
1	Indaziflam	56	100	50
2	Rimsulfuron	70	100	100
3	Flumioxazin	882	38	63
4	Pendimethalin	4,259	80	88
5	Pyroxasulfone	150	68	75
6	Pyroxasulfone	225	75	88
7	Pyroxasulfone	300	100	100
8	Pyroxasulfone Pendimethalin	150 4,259	75	75
9	Pyroxasulfone Pendimethalin	225 4,259	93	75
10	Flumioxazin + Pyroxasulfone	118 150	75	88
11	Flumioxazin + Pyroxasulfone	178 225	75	93
12	Pyroxasulfone Rimsulfuron	150 70	93	100
13	Pyroxasulfone Rimsulfuron	225 70	88	100
14	Oxyfluorfen Pendimethalin	2,018 4,259	80	84
	P-value		0.880	0.310

[1]Hare barley began to senesce approximately 90DAT
[2]DAT = days after treatment