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Corresponding author:
Matthew Fatino; Email: mfatino@ucdavis.edu

Refining use of chemigated rimsulfuron for branched broomrape management in California processing tomato

Matthew Fatino[1] and Bradley D. Hanson[2]

[1]Postdoctoral Researcher, Department of Plant Sciences, University of California, Davis, Davis, CA, USA and [2]Cooperative Extension Specialist, Department of Plant Sciences, University of California, Davis, Davis, CA, USA

Abstract

Branched broomrape management is of increasing concern to California processing tomato growers. Field research was conducted in 2023 and 2024 to evaluate various application timings of chemigated rimsulfuron alone, preplant-incorporated (PPI) sulfosulfuron paired with chemigated rimsulfuron, and foliar maleic hydrazide alone and paired with PPI sulfosulfuron and chemigated rimsulfuron. In 2023, all treatments with 70 g ai ha^{-1} rimsulfuron, alone or paired with PPI sulfosulfuron, reduced broomrape emergence 77% to 92% compared to the nontreated control. In 2024, broomrape pressure was higher, and all rimsulfuron treatments reduced broomrape emergence 68% to 86% compared to the control. In both years, five applications of foliar maleic hydrazide reduced broomrape emergence through at least mid-season. The 2024 experiment included a combination treatment of PPI sulfosulfuron, chemigated rimsulfuron, and foliar maleic hydrazide, which resulted in <4 broomrape clusters plot^{-1}. In a 2024 grower-scale demonstration trial, two application regimes totaling 70 g ai ha^{-1} of chemigated rimsulfuron reduced broomrape emergence 83% to 89% compared to the control. Overall, chemigated rimsulfuron applied at various timings and rates totaling 70 g ai ha^{-1} reduced broomrape emergence by two-thirds or more compared to the nontreated plots. No crop injury was observed in trials with rimsulfuron, sulfosulfuron, or maleic hydrazide treatments in small-plot trials or with rimsulfuron in the grower-scale demonstration trial. Under a recently approved 24(c) Special Local Need label, California growers can use three applications of rimsulfuron applied via chemigation to suppress broomrape in known infested fields or to reduce the risk of broomrape establishment in fields of concern for this quarantine pest. Promising results from sulfosulfuron and maleic hydrazide suggest that registering additional herbicides could help develop even more robust branched broomrape management programs.

Introduction

Processing tomato is a major cash crop in the Sacramento and San Joaquin Valleys of California and is among the top ten crops by farm gate value in the state, worth more than US$1 billion per year (USDA 2023). California produces approximately 30% of the worldwide processing tomato crop, with more than 11.5 million mT produced in 2023, with an average yield of more than 113 mT ha^{-1} (USDA 2023; WPTC 2023). California processing tomatoes are grown in a highly managed cropping system where they are mechanically transplanted, intensively managed with fertilizer and pesticide programs, and mechanically harvested (Geissler and Horwath 2016).

Broomrapes (*Orobanche* and *Phelipanche* spp.) are parasitic plants native to the Mediterranean basin (Parker and Riches 1993). Broomrapes are achlorophyllic holoparasites that gain nutrients from a host plant's root system (Joel 2009; Parker 2008). Some broomrape species have narrow host ranges, while others, such as branched broomrape and Egyptian broomrape (*Phelipanche aegyptiaca* [Pers.] Pomel), have wide host ranges that include many agricultural crop families grown in California, including crop plants from the Alliaceae, Asteraceae, Brassicaceae, Cannabaceae, Cucurbitaceae, Fabaceae, and Solanaceae families (Parker and Riches 1993). Among the Solanaceous crops, tomatoes are highly susceptible to parasitism by branched broomrape (Osipitan et al. 2021).

Broomrapes respond to strigolactones exuded from their host plants to initiate germination (Parker 2008). After receiving the strigolactone signal, broomrape seeds germinate and produce a small radicle that attaches to a host plant's root. After successful attachment, a tubercle forms, and upon full development, multiple stems emerge above the soil surface to flower and produce seed.

In California, two species of *Phelipanche* have been reported: branched and Egyptian broomrape. Branched broomrape has been present in the state since the early 1900s, though it was thought to have been eradicated by the late 1980s, after a coordinated effort by industry and state stakeholders (Gaimari and O'Donnell 2008; Jain and Foy 1989). However, in recent years, it has been reported in numerous commercial fields in the Sacramento Valley (Osipitan et al. 2021). Egyptian broomrape has only been reported in three fields in the United States, all in the Sacramento Valley of California, and is currently thought to be eradicated after fumigation of those fields (Miyao 2017). Branched broomrape is an "A-listed" quarantine pest in California, requiring crop destruction if found and reported in a commercial field (Kelch 2017). The resurgence of branched broomrape presents a major threat to regional and statewide production due to its regulatory status (Kelch 2017; Osipitan et al. 2021). In addition to crop loss in the reporting year, a hold order is placed that bars the planting of host crops for several more years, presenting affected growers with a massive cumulative economic loss (Miyao 2017).

Many species of broomrapes are widespread throughout crop production areas in Mediterranean climates and present major difficulty to growers. Through decades of applied research, researchers in Israel developed a decision support system and treatment protocols for management of Egyptian and branched broomrapes in their processing tomato systems (Eizenberg and Goldwasser 2018; Eizenberg et al. 2004; Hershenhorn et al. 1998, 2009). The PICKIT decision support system relies on a thermal time model (growing degree days; GDDs) to predict broomrape phenological stages, and on the basis of these predictions, ALS inhibitor herbicides are applied at very low rates at times intended to target specific broomrape life stages and attachment to the host crop (Eizenberg et al. 2012; Ephrath et al. 2012). The PICKIT system includes several regimes that depend on broomrape infestation levels, with most protocols based on preplant-incorporated (PPI) or water-incorporated sulfosulfuron followed by multiple applications of chemigated imazapic.

In California, research began in 2020 to validate and generate registration support data for several herbicides used in the PICKIT regimes (Fatino 2024; Fatino and Hanson 2022). After two seasons, it became clear that there were significant regulatory barriers to registering imazapic in California, and research pivoted to imazamox, which is registered in the state (Anonymous 2022b). However, field studies with chemigated imazamox in 2020 to 2021 in California and Chile indicated that the margin of safety of chemigated imazamox was insufficient in processing tomatoes (Fatino 2024).

In 2022, rimsulfuron was also evaluated as a foliar and chemigation treatment following success in reducing broomrape emergence in Israeli and Italian processing tomato systems (Conversa et al. 2017; Eizenberg and Goldwasser 2018). In Israel, rimsulfuron was evaluated as a postemergence treatment incorporated with overhead irrigation (Eizenberg and Goldwasser 2018). Israeli results from rimsulfuron incorporated with irrigation were good, but not as successful as with sulfosulfuron, which would later become the basis of the PICKIT system (Eizenberg and Goldwasser 2018). In Italy, rimsulfuron was applied three times via chemigation through surface drip irrigation, which was successful in reducing broomrape emergence (Conversa et al. 2017). These results and other research would eventually lead to chemigated rimsulfuron being labeled in Italy for branched broomrape control (Anonymous 2018).

In the United States and many other global markets, the plant growth regulator maleic hydrazide (MH) is commercially used as a sprouting inhibitor in onion (*Allium cepa* L.), garlic (*Allium sativum* L.), shallot (*Allium ascalonicum* L.), and potato (*Solanum tuberosum* L.) (Anonymous 2024; Venezian et al. 2017). Israeli researchers also evaluated MH for Egyptian broomrape control in processing tomato (Venezian et al. 2017). Venezian et al. reported that MH had a slight inhibitory effect on broomrape germination and greatly inhibited early development stages in laboratory studies. These results indicate that initial attachment and establishment of tubercles in the host root tissue are the main developmental stages inhibited by MH. In field studies, Venezian et al. reported that sequential foliar applications of MH reduced broomrape emergence in processing tomatoes but that sequential chemigated applications were not as successful in reducing broomrape emergence and that some treatments adversely affected yield.

Rimsulfuron is widely used in California processing tomato production as a preemergence or foliar selective broadleaf herbicide but was not registered for application via chemigation until 2022 (Anonymous 2022a). After the chemigation label was approved for use in California tomato (Anonymous 2022a), further research was conducted in 2023 and 2024 to validate the performance for branched broomrape management and to refine application timings and techniques. In addition, research was conducted to validate two protocols utilizing MH for branched broomrape management and to develop support data for potential future registration.

Materials and Methods

Field trials were conducted during 2023 and 2024 in a commercial tomato field near Woodland, CA (38.758°N, 121.771°W). This field was first reported to be infested with branched broomrape in 2019, and a high broomrape population has been well documented in subsequent efficacy studies (Fatino and Hanson 2022). The soil composition at this site was 48% sand, 33% silt, and 19% clay, with an organic matter content of 2.13% and pH 7.20. The field site was set up with raised 1.5-m beds with a single 22-mm drip line buried 20 to 25 cm deep in the center of the bed with 0.6 L hr^{-1} emitters spaced every 30 cm. Individual plots were 30 m long and arranged in a randomized complete-block design with four replicates.

Treatments focused on evaluations of sulfosulfuron, rimsulfuron, and MH alone and in combination with one another at several timings (Tables 1 to 3). PPI and foliar herbicides were applied using a CO_2 -pressurized backpack sprayer with a three-nozzle boom delivering 187 L ha^{-1} with TeeJet® AIXR 11002 nozzles (TeeJet® Technologies, Glendale Heights, IL, USA), and PPI applications were mechanically incorporated with a power incorporator and bed shaper after application. 'HM 58841' tomato transplants were mechanically transplanted with 30-cm in-row spacing in a single line. Chemigation applications were made to single bed plots during irrigation set by connecting a CO_2-pressurized 3-L bottle of herbicide solution between the supply line and buried drip line and injecting the mixture over 10 to 15 min. The irrigation set continued for approximately 1 h after the chemigation treatment to flush lines and distribute the herbicide into the tomato root zone.

The 2023 trial focused on slight modifications of the rimsulfuron application schedules. Chemigation and foliar applications were made according to a GDD schedule (Eizenberg and Goldwasser 2018) or a simplified days after transplanting (DATr) schedule (Tables 1 and 2). These treatments were applied as rimsulfuron alone or in combination with PPI sulfosulfuron. The annual maximum use rate for foliar or chemigated rimsulfuron in California is 70 g ai ha^{-1}; the 24(c) calls for three applications of 23.3 g ai ha^{-1} to utilize the maximum annual use rate (Anonymous 2022a). A secondary goal in 2023 was to evaluate GDD and DATr protocols in which this annual

Table 1. Application dates from two branched broomrape efficacy trials conducted near Woodland, CA.[a]

Treatment	2023	2024	Demo
Preplant incorporated	5 May	28 Mar	—
Transplant	21 May	9 Apr	24 May
Chemigation			
400 GDD	12 Jun	9 May	—
600 GDD	20 Jun	16 May	—
800 GDD	30 Jun	30 May	—
1,000 GDD	—	6 Jun	—
20 DATr	—	3 May	18 Jun
30 DATr	14 Jun	9 May	28 Jun
40 DATr	—	20 May	8 Jul
50 DATr	11 Jul	30 May	18 Jul
70 DATr	5 Aug	6 Jun	—
Foliar MH, rimsulfuron			
100 GDD	31 May	22 Apr	—
Foliar MH			
200 GDD	5 Jun	27 Apr	—
400 GDD	12 Jun	9 May	—
700 GDD	23 Jun	28 May	—
1,000 GDD	5 Jul	6 Jun	—

[a]Abbreviations: DATr, days after transplant; GDD, growing degree days; MH, maleic hydrazide.

maximum amount was split into four treatments of 17.4 g ai ha^{-1}: one foliar application for nonbroomrape broadleaf weed control and three chemigated applications for broomrape control. Last, MH was applied according to two protocols described by Venezian et al. (2017): a constant-rate protocol with five applications of 400 g ai ha^{-1} and a split-rate protocol with two applications of 270 g ai ha^{-1} followed by three applications of 540 g ai ha^{-1}.

The 2024 trial continued to evaluate chemigated rimsulfuron alone and paired with sulfosulfuron, as well as foliar MH alone and paired with sulfosulfuron and rimsulfuron, applied according to both GDD and DATr schedules (Tables 1 and 3). In 2024, the annual maximum rate of rimsulfuron was split into three chemigated applications of 23.3 g ai ha^{-1} per the 24(c) label, one foliar application, three chemigated applications of 17.4 g ai ha^{-1}, and five chemigated applications of 13.9 g ai ha^{-1}. Additionally, to generate data relevant to tomato markets in Chile, the annual maximum rate of rimsulfuron in Chile was split into three chemigated applications of 10 g ai ha^{-1}. Collaborators at the University of California, Davis (UC Davis) Chile have worked with UC Davis researchers in the past to develop herbicide programs for their tomato systems, which have significantly higher populations of branched broomrape than those in California (Fatino 2024). This trial also included, for the first time, a chemigated sulfosulfuron treatment compared to the PPI treatment and chemigated rimsulfuron.

To validate and support data collected from small-plot trials in 2023 and 2024, a larger-scale demonstration study was conducted in a different branched broomrape–infested commercial field located near Woodland, CA. This trial occurred within a commercially planted processing tomato crop and, as a result, evaluated only two permutations of the 24(c) Matrix label. The field was set up with raised 2-m beds with a single 22-mm drip line buried 30 cm deep in the center of the bed with 0.6 L hr^{-1} emitters spaced every 30 cm. Individual plots were 400 m long and arranged in a randomized complete-block design with three replicates. 'HM 8237' tomato transplants were mechanically transplanted with 30-cm in-row spacing in two lines on each bed. Chemigation treatments were mixed in a 100-L tank, and applications were made into individual beds with an electric pump during the last third of an irrigation set (Table 4). Treatments were applied according to a DATr schedule (Table 1).

Data Collection and Analysis

In the 2023 and 2024 small-plot field experiments, broomrape emergence was monitored weekly, and clusters of emerged shoots were marked with wire construction flags (Figure 1). These trials were terminated at commercial tomato maturity, and the number of flags in each plot was recorded. In the 2024 demonstration study, broomrape emergence was measured four times throughout the growing season, and tomato yield was collected using a commercial Johnson mechanical harvester (Oxbo, Woodland, CA, USA) and weigh cart equipped with a scale. Tomato yield per 400-m plot was collected at commercial maturity on October 2, 2024.

Data were analyzed with a one-way analysis of variance followed by a Tukey honestly significant difference test in RStudio (version 1.2.5033; RStudio Team 2021).

Results and Discussion

2023

No tomato crop injury was observed in the treated plots (data not shown). All treatments reduced broomrape emergence compared to the nontreated controls, but there were no significant differences among treatments (Table 2). The nontreated control plots had the highest broomrape emergence with 26 clusters 30-m plot^{-1} on average, while Treatment 7 (sulfosulfuron + rimsulfuron ×3 GDD) had the lowest emergence at 2 clusters plot^{-1} on average. Although there were no significant differences in broomrape emergence among treatment timing regimes, treatments applied according to the GDD schedule tended to have slightly lower broomrape emergence. The GDD schedule had the second and third chemigation applications applied earlier than the DATr schedule did (Table 1). On the basis of this observation, the DATr treatment timings were adjusted to 20, 30, and 40 DATr instead of 30, 50, and 70 DATr in 2024. The split-rate MH protocol and the constant-rate protocol resulted in similar levels of broomrape emergence, with 5 and 4 clusters plot^{-1} on average, respectively, in the 2023 trial (Table 2).

2024

No tomato crop injury was observed in any of the treated plots (data not shown). Broomrape emergence was much higher in 2024 than in 2023, with 111 versus 24 clusters plot^{-1} in the nontreated controls, respectively (Tables 2 and 3). Most treatments reduced broomrape emergence compared to the nontreated control; the only treatments that did not reduce cumulative broomrape emergence were PPI sulfosulfuron alone and the constant-rate foliar MH (Treatments 8 and 10; Table 3). Interestingly, the PPI sulfosulfuron treatment had slow but steady broomrape emergence as observed in the control plots, while the MH treatment had extremely low broomrape emergence until about 5 wk after the last treatment, at which point, there was several weeks' far greater late-season emergence than with the nontreated control (data not shown). Although there were no significant differences in broomrape emergence among the other treatments, the treatment with the lowest broomrape emergence was the full-stack treatment (Treatment 12), with 4 clusters plot^{-1} on average (Table 3).

In the large-scale demonstration study, no tomato crop injury was observed in any of the treated plots (data not shown). Both chemigated rimsulfuron treatments had significantly reduced

Table 2. Treatments from a 2023 broomrape efficacy study conducted near Woodland, CA.[a,b]

Treatment	Common name	Rate	Application	Timing	Broomrape emergence
		g ai ha^{-1}			clusters 30 m^{-1}
1. Nontreated control 1					28 a
2. Nontreated control 2					24 a
3. Sulfosulfuron solo	Sulfosulfuron	37.5	PPI		8 b
4. Rimsulfuron solo ×4 GDD	Rimsulfuron	17.4	Foliar ×1; chem ×3	100 (F), 400, 600, 800 GDD	5 b
5. Rimsulfuron solo ×4 DATr	Rimsulfuron	17.4	Foliar ×1, chem ×3	100 GDD (F), 30, 50, 70 DATr	5 b
6. Sulfosulfuron + rimsulfuron ×4 GDD	Sulfosulfuron	37.5	PPI		3 b
	Rimsulfuron	17.4	Foliar ×1; chem ×3	100 (F), 400, 600, 800 GDD	
7. Sulfosulfuron + rimsulfuron ×3 GDD	Sulfosulfuron	37.5	PPI		2 b
	Rimsulfuron	23.3	Chem ×3	400, 600, 800 GDD	
8. Sulfosulfuron + rimsulfuron ×3 DATr	Sulfosulfuron	37.5	PPI		6 b
	Rimsulfuron	23.3	Chem ×3	30, 50, 70 DATr	
9. MH constant rate	Maleic hydrazide	400 ×5	Foliar ×5	100, 200, 400, 700, 1,000 GDD	5 b
10. MH split rate	Maleic hydrazide	270 ×2, 540 ×3	Foliar ×5	100, 200, 400, 700, 1,000 GDD	4 b
P-value					<0.0001

[a]Abbreviations: chem, chemigated; DATr, days after transplant; GDD, growing degree days; MH, maleic hydrazide; PPI, preplant incorporated.
[b]Means that share the same letter are not significantly different according to Tukey's HSD (α = 0.05).

Table 3. Treatments from a 2024 broomrape efficacy study conducted near Woodland, CA.[a,b]

Treatment	Common name	Rate	Application	Timing	Broomrape emergence
		g ai ha^{-1}			clusters 30 m^{-1}
1. Nontreated control					111 ab
2. Rimsulfuron ×3	Rimsulfuron	23.3	Chem ×3	400, 600, 800 GDD	36 c
3. Rimsulfuron ×4	Rimsulfuron	17.4	Foliar, chem ×3	200 (F), 400, 600, 800 GDD	25 c
4. Rimsulfuron ×5	Rimsulfuron	13.9	Chem ×5	200, 400, 600, 800, 1,000 GDD	15 c
5. Sulfosulfuron + rimsulfuron ×3 GDD	Sulfosulfuron	37.5	PPI		18 c
	Rimsulfuron	23.3	Chem ×3	400, 600, 800 GDD	
6. Sulfosulfuron + rimsulfuron ×3 DATr	Sulfosulfuron	37.5	PPI		34 c
	Rimsulfuron	23.3	Chem ×3	25, 35, 45 DATr	
7. Sulfosulfuron + rimsulfuron late DATr	Sulfosulfuron	37.5	PPI		32 c
	Rimsulfuron	23.3	Chem ×3	30, 50, 70 DATr	
8. Sulfosulfuron alone	Sulfosulfuron	37.5	PPI		114 a
9. Sulfosulfuron drip	Sulfosulfuron	12.5	Chem ×3	400, 600, 800 GDD	16 c
10. MH constant rate	Maleic hydrazide	400 ×5	Foliar ×5	100, 200, 400, 700, 1,000 GDD	44 bc
11. MH split rate	Maleic hydrazide	270 ×2, 540 ×3	Foliar ×5	100, 200, 400, 700, 1,000 GDD	27 c
12. Full stack	Sulfosulfuron	37.5	PPI		
	Rimsulfuron	23.3	Chem ×3	400, 600, 800 GDD	
	Maleic hydrazide	270 ×2, 540 ×3	Foliar ×5	100, 200, 400, 700, 1,000 GDD	4 c
13. Rim Chile rate	Rimsulfuron	10	Chem ×3	400, 600, 800 GDD	40 c
P-value					<0.0001

[a]Abbreviations: chem, chemigated; DATr, days after transplant; GDD, growing degree days; MH, maleic hydrazide; PPI, preplant incorporated.
[b]Means that share the same letter are not significantly different according to Tukey's HSD (α = 0.05).

Table 4. Treatments from a 2024 broomrape management demonstration study conducted near Woodland, CA.[a,b]

Treatment	Common name	Rate	Application	Timing	Broomrape emergence	Tomato yield
		g ai ha^{-1}		DATr	clusters 400 m^{-1}	kg 400 m^{-1}
1	Nontreated control				122 a	9,306 a
2	Rimsulfuron ×3	23.3	Chem ×3	20, 30, 40	21 b	9,143 a
3	Rimsulfuron ×4	17.4	Chem ×4	20, 30, 40, 50	15 b	9,158 a
P-value					0.0003	0.44

[a]Abbreviations: chem, chemigated; DATr, days after transplant.
[b]Means that share the same letter are not significantly different according to Tukey's HSD (α = 0.05).

Figure 1. Colored flags in a 2024 field trial near Woodland, CA, marking broomrape emergence over time in a nontreated control plot (left) and a 23.3 g ai ha^{-1} ×3 chemigated rimsulfuron–treated plot (right) approximately 110 d after transplant.

broomrape emergence versus the nontreated control (Table 4). The control plots had an average of 122 clusters 400-m $plot^{-1}$, while the 22.3 g ai ha^{-1} ×3 treatment had an average of 21 clusters $plot^{-1}$ and 17.4 g ai ha^{-1} ×4 had an average of 15 clusters $plot^{-1}$ (Table 4). No statistical differences emerged between the two chemigated rimsulfuron treatments (Table 4). Tomato yield for each 400-m plot was measured using a commercial mechanical harvester. Yield ranged from 9,143 to 9,306 kg $plot^{-1}$ (Table 4). There were no significant differences in yield among treatments (Table 4). Given the significant reduction in broomrape emergence with both chemigated rimsulfuron treatments and comparable yields versus control, these results could encourage growers to adopt the 24(c) rimsulfuron protocol as a preventive treatment in fields at risk of branched broomrape infestation.

After two field seasons of efficacy trials, it is clear that chemigated rimsulfuron treatments totaling 70 g ai ha^{-1} can effectively reduce broomrape emergence compared to nontreated controls. PPI sulfosulfuron results were mixed: in 2023, this treatment reduced broomrape emergence significantly compared to the nontreated control, but in 2024, it was not effective alone but appeared to be beneficial in combination with chemigated rimsulfuron and foliar MH. Foliar MH provided variable results: in 2023, both protocols reduced emergence compared to control, and in 2024, there was very good broomrape suppression until mid-July, when a flush of emergence reduced the cumulative efficacy of both protocols. Further research could focus on different timings of this treatment to potentially extend the excellent early-season control seen in the 2024 trials. The full-stack treatment of PPI sulfosulfuron, chemigated rimsulfuron, and foliar MH provided a 96% reduction in broomrape emergence in 2024. This was the best treatment by far, and further research will continue to evaluate these chemistries and generate additional data to support potential registration for their use in California tomato.

In 2024, the GDD schedule was applied earlier than the early DATr schedule and had numerically lower emergence than both the early (Treatment 6) and late (Treatment 7) DATr treatments (Table 3). Moving forward, a simplified DATr-based schedule of three applications applied every 10 d between 20 and 50 DATr will be recommended to growers. This recommendation more closely follows the Italian Executive label (Anonymous 2018). Future research will continue to evaluate chemigated sulfosulfuron, significantly reducing broomrape emergence in 2024. This material is widely used in Israel, where a foliar application is incorporated with overhead irrigation (Eizenberg and Goldwasser 2018). However, this method is not very feasible in California, where the vast majority of tomato fields are irrigated solely with subsurface drip irrigation. However, applying sulfosulfuron as a chemigated treatment may be a way to achieve similar control to the Israeli treatments within the confines of California agronomic practices. Under the current 24(c) label for chemigated rimsulfuron, the full annual maximum rate is split into three chemigation treatments, leaving none available for broadleaf weed control (Anonymous 2022a). The use of chemigated sulfosulfuron as a portion of the broomrape management program could allow some portion of the allowable annual use of rimsulfuron to be used as a foliar treatment for broadleaf weed control, particularly for selective control of nightshades (*Solanum* spp.). Treatment 3 also aimed to address this drawback, with one foliar application for broadleaf weed control and three for broomrape control. It

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performed similarly to other rimsulfuron treatments and had statistically similar broomrape emergence as Treatment 2, with three chemigated applications (Table 3).

Practical Implications

In late 2022, the California tomato industry successfully acquired a 24(c) label for chemigated rimsulfuron (Anonymous 2022a). This protocol effectively reduced broomrape emergence upward of 70% in the relatively low levels of infestation currently present in California (Table 3). There is some evidence that the more complicated GDD-based protocol may be slightly more effective than the DATr-based protocol; however, there were no statistical differences between the two timing protocols, and current recommendations have not changed. There is also some evidence to suggest that starting chemigation treatments 10 d earlier (20, 30, 40 DATr vs. 30, 50, 70 DATr) and that more numerous applications of lower doses of rimsulfuron may improve season-long efficacy, but these results should be validated with further research and surveys.

While none of the treatments evaluated reached eradication level and may not be sufficiently effective in a highly infested field due to the regulatory status of branched broomrape, rimsulfuron-based protocols are likely to provide significant risk-reduction benefits in fields with low infestations or in fields that are at risk of seed introduction but not currently known to be infested. Owing to the unique status of branched broomrape and the unconventional application method, substantial outreach efforts have been and are continuing to be made to educate growers and pest managers on chemigation protocols and strategies and on the benefits of using chemigated rimsulfuron for branched broomrape management in California.

Results from these experiments have been shared with researchers and tomato industry professionals in Chile to facilitate future research there and for the potential registration of chemigated rimsulfuron in their tomato systems. Researchers in Chile plan to evaluate a similar protocol in commercial fields with significantly higher infestations than those in California. Results from the 2024 full-stack treatment indicate high levels of efficacy (96% reduction in broomrape emergence) and are very promising for future broomrape management in California but will require substantial research to generate registration support data.

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