Evaluation of efficacy of PICKIT system for branched broomrape control in California-grown processing tomatoes (IR-4 Project: IS00330)

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Broomrapes (*Phelipanche spp.)* are parasitic weeds native to the Middle East. The biology of broomrape makes its control via conventional weed control practices very difficult. Broomrape seeds germinate after receiving a signal from a suitable host plant and quickly attach to the host roots via a specialized structure known as a haustorium. Most of the broomrape lifecycle is spent below the soil surface. The above ground portions of the plant lack chlorophyll and quickly produce a large amount of seed, which are highly persistent in the soil seedbank. Broomrape is not currently common in California but is an "A-listed" noxious weed and has been detected in several processing tomato fields in recent years.

A study was conducted in a commercial tomato field north of Woodland, CA, to evaluate the crop-safety of the Israeli-developed PICKIT decision support system for control of branched broomrape (*Phelipanche ramosa)* in processing tomato. The PICKIT decision support system relies on a thermal time model (Growing Degree Days) to predict broomrape phenological stages. Based on the decision support system, ALS inhibitor herbicides are applied at times intended to target specific broomrape life stages and attachment to the host crop.

The commercial field site is infested with branched broomrape (*Phelipanche ramosa)* making it an excellent resource for testing the efficacy of the PICKIT protocol on branched broomrape control in California tomato systems. The soil composition at this site was Yolo silt loam (USDA NRCS Wed Soil Survey). Plots were 100 feet long on 60-inch beds with two plant lines down each bed. 'BQ273' processing tomato transplants were planted at a 12-inch spacing within the row. Each bed had two drip lines: one 7/8-inch drip line buried at 10 inches and one 1-inch drip line buried at 12 inches in the center of the bed. The 7/8-inch drip line was terminated at the ends of each plot and was the dedicated chemigation line with 0.16 gph emitters with 12" spacing. The 1-inch line was used for crop irrigation and fertigation of the entire experimental area. Plots were arranged in a randomized complete block design with four replications.

PPI applications of sulfosulfuron were made on March 27, 2020. Sulfosulfuron was applied using a backpack sprayer and three-nozzle boom delivering 30 GPA with AIXR 1103 nozzles at 28 PSI. PPI treatments were mechanically incorporated to 3 inches after application on March 27, 2020. In addition to the experimental treatments, the entire plot area was treated with the grower's preplant incorporated tank mix, which consisted of S-metolachlor (2 pt/ac), pendimethalin (1pt/ac), metribuzin (1pt/ac), and diazinon (1gal/ac) on March 27, 2020. Tomatoes were mechanically transplanted with a two-row transplanter on March 30, 2020. A foliar application of 2.5 oz/ac rimsulfuron was made by the grower to the entire plot area after transplanting.

Drip herbicide injection (chemigation) applications were made using CO_2 to push chemigation mix into the 7/8-inch chemigation lines in each plot. Treatments were applied to 2 replicate plots at once; plots of the same treatment in replications 1 and 2 were treated together while replications 3 and 4 were treated together. Herbicide treatments mixed in 11 L of solution which

was injected into the already-running irrigation system over approximately 15 minutes, followed by 20 minutes of water to flush the lines. The PICKIT system's thermal time model is based off growing degree days (GDD), and called for applications at 400, 500, 600, 700, and 800 GDD depending on treatment (Table 1). Foliar imazapic treatments were made on June 12, 2020 and June 25, 2020 with a 2-nozzle backpack sprayer delivering 30 GPA with AIXR 1103 nozzles at 28 PSI.

Broomrape scouting was done 1-3 times weekly starting on June 1, 2020, and individual clusters were marked with a 24-inch wire construction flag, with different colors representing each week's emergence. Clusters were counted and recorded. Cluster means were analyzed with a one-way analysis of variance followed by Tukey-HSD test via the agricolae package in R.

Table 1. Growing Degree Day targets and actual application dates in a 2020 tomato field experiment near Woodland, CA.

Growing Degree Day* Target	**Actual Application Date**
PPI	3/27/2020
400	5/2/2020
500	5/8/2020
600	5/14/2020
700	5/22/2020
800	5/26/2020
Imazapic POST at broomrape emergence	6/12/2020
Rimsulfuron (Treatment 12)	6/12/2020
Imazapic 21-day after initial broomrape emergence	6/25/2020**

* Cumulative Growing Degree Days (GDD) were calculated after tomato transplanting date by using the formula $GDD = \sum(\bar{T} - T_b)$, where $\bar{T}$ is mean daily temperature and T_b is the base temperature set at 10 °C (50 degrees Fahrenheit).

** This did not coincide with the recommended application timing of broomrape emergence and 21 days after; instead, the first application was made one week after broomrape emergence and the second application was 13 days after that.

Table 2. PICKIT treatments in a 2020 processing tomato field experiment near Woodland, CA.

		Rate	**Rate**		
Trt. No	**Treatment**	oz ai/a	g ai/ha	**Application**	**GDD Appl.***
1	Untreated Check	--	--		
2	Treflan	3 pt/A		PPI	
	Matrix	1 oz wt/A		PPI	
3	Sulfosulfuron (Outrider)	0.535	37.5	PPI	
	Imazapic (Cadre)	0.0685	4.8	CHEM x5	400, 500, 600, 700, 800
4	Sulfosulfuron (Outrider)	0.535	37.5	PPI	
	Imazapic (Cadre)	0.0685	4.8	CHEM x2	400, 600
5	Imazapic (Cadre)	0.0343	2.4	POSTx2	
6	Sulfosulfuron (Outrider)	0.535	37.5	PPI	
	Imazapic (Cadre)	0.137	9.6	CHEM x5	400, 500, 600, 700, 800
7	Sulfosulfuron (Outrider)	1	70	PPI	
	Imazapic (Cadre)	0.137	9.6	CHEM x2	400, 600
8	Imazapic (Cadre)	0.0685	4.8	POSTx2	
9	Sulfosulfuron (Outrider)	0.535	37.5	PPI	
	Imazamox (Raptor)	0.0685	4.8	CHEM x5	400, 500, 600, 700, 800
10	Sulfosulfuron (Outrider)	0.535	37.5	PPI	
	Imazapyr (Habitat)	0.0685	4.8	CHEM x5	400, 500, 600, 700, 800
11	Sulfosulfuron (Outrider)	0.535	37.5	PPI	
	Imazethapyr (Pursuit)	0.0685	4.8	CHEM x5	400, 500, 600, 700, 800
12	Rimsulfuron (Matrix)	2 oz wt/A		POST	

* PPI: preplant incorporated POST: post emergence CHEM: Chemigated. Cumulative Growing Degree Days (GDD) were calculated after tomato transplanting date by using the formula $GDD = \sum(\bar{T} - T_b)$, where $\bar{T}$ is mean daily temperature and T_b is the base temperature set at 10 ℃ (50 degrees Fahrenheit).

** The entire experimental area was treated with the grower's preplant incorporated herbicide program of S-metolachlor (2pt/ac), pendimethalin (1pt/ac), metribuzin (1pt/ac), and diazinon (1gal/ac) and also with a post-transplant application of 2.5 oz /ac Matrix.

***Note: an earlier version of this report had treatments 9, 10, 11 listed as a 2x program (70g sulfosulfuron and 9.6 g imaz_x). Those rates were used in a separate rotational crop safety study but this trial included the 1x program of 37.5 and 4.8g ai/ha as listed in this version.

Table 3. Cumulative branched broomrape emergence in response to PICKIT treatments in a commercial tomato field near Woodland CA in 2020.

Trt. No	Treatment*	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10
1	Untreated Check	2a	2.8a	6.3ab	9.3ab	15.8abc	21.0abc	23.0ab	24.8ab	25.0ab
2	Treflan Matrix	3.8a	4.3a	8.8ab	13.0ab	28.0ab	36.5ab	43.0a	45.0a	45.0a
3	Sulfosulfuron (Outrider) Imazapic (Cadre)	2.5a	3.0a	5.8ab	7.5ab	11.8abc	14.8bc	17.5b	18.0b	18.3b
4	Sulfosulfuron (Outrider) Imazapic (Cadre)	2.8a	3.0a	4.5ab	7.5ab	9.3bc	12.0c	12.8b	13.8b	13.8b
5	Imazapic (Cadre)	2.3a	3.3a	4.3ab	6.5b	9.0bc	10.3c	10.5b	10.5b	11.0b
6	Sulfosulfuron (Outrider) Imazapic (Cadre)	0a	0.3a	1.3b	2.3b	3.8c	4.3c	4.8b	5.0b	5.3b
7	Sulfosulfuron (Outrider) Imazapic (Cadre)	0a	0.0a	2.3b	5.8b	10.0abc	14.3bc	15.8b	17.5b	17.8b
8	Imazapic (Cadre)	2.5a	4.0a	5.8ab	7.3ab	7.5bc	7.5c	7.5b	7.5b	7.5b
9	Sulfosulfuron (Outrider) Imazamox (Raptor)	1.0a	2.5a	4.5ab	6.0b	10.0abc	14.8bc	15.5b	16.0b	16.5b
10	Sulfosulfuron (Outrider) Imazapyr (Habitat)	4.0a	5.0a	6.8ab	9.5ab	12.8abc	15.0abc	16.0b	16.5b	16.5b
11	Sulfosulfuron (Outrider) Imazethapyr (Pursuit)	2.8a	3.8a	5.0ab	8.3ab	10.8abc	14.3bc	15.3b	15.3b	15.5b
12	Rimsulfuron (Matrix)	6.8a	9.3a	15.3a	22.0a	30.8a	39.0a	43.3a	44.5a	45.3a

*See Table 1 for treatment details.

Broomrape counts (#/30 m row)				
Row	**Rep 1**	**Rep 2**	**Rep 3**	**Rep 4**
1	14	14	48	11
2	42	51	19	19
3	30	15	14	30
4	7	6	11	3
5	4	33	10	58
6	2	2	43	16
7	10	9	9	15
8	2	0	5	44
9	6	2	22	2
10	13	39	11	14
11	5	24	32	33
12	33	42	36	27

Treatment number				
Row	**Rep 1**	**Rep 2**	**Rep 3**	**Rep 4**
1	1	7	12	9
2	2	2	7	10
3	3	3	11	1
4	4	6	3	6
5	5	1	10	12
6	6	8	2	3
7	7	11	6	8
8	8	5	9	2
9	9	4	1	5
10	10	12	8	4
11	11	10	4	11
12	12	9	5	7

Figure 1. Heat map illustrating broomrape cluster density in field in late July 2020. Average number of clusters per 30 m plot illustrated in the colored figure on left, with corresponding treatments in figure on right. Lighter green represents low average number of clusters and darker red represents high average number of clusters.

Results

After 10 weeks of broomrape emergence monitoring, the trifluralin/rimsulfuron treatment (#2) and the POST rimsulfuron treatment (#12) had more broomrape cluster per plot than all the PICKIT treatments (Table 2) with more than 45 cluster per plot. However, the untreated check (which received only the grower treatment) had intermediate broomrape emergence (25 clusters per plot) compared to the least effective and most effective which suggest the treatment effects may have been masked or enhanced by spatial variability in the field to some degree (Figure 1).

Numerically, treatment 6 had the fewest broomrape clusters with 5.3 per plot followed by treatment 8 with 7.5 clusters per plot. Treatment 6 was the most intense PICKIT treatment with PPI sulfosulfuron followed by five applications of imazapic via chemigation, both applied at twice the suggested use rate. Similarly, treatment 8 was the highest rate of foliar-applied imazapic applied twice after broomrape emergence was observed. The other PICKIT treatments and the alternative imidazolinone herbicide treatments resulted in 11-18 clusters per plot.

Discussion

Broomrape distribution and emergence was not uniform throughout the field (Figure 1) which complicates interpretation of these data. However, although control was incomplete, there was a trend for reductions in broomrape clusters for most of the PICKIT-related treatments vs the grower standard.

Broomrape was initially observed around May 28 and full field scouting began June 1st, a week after the 800 GDD treatments and nearly 4 weeks after the 400 GDD treatment. By the end of the second week of scouting, (week 2 in Table 3), most treatments had some plots with broomrape plants present. This suggests that our treatment timings may need to be adjusted for this species of broomrape in this soil and production system. Researchers elsewhere have observed that branched broomrape appears to develop more slowly than Egyptian broomrape (Goldwasser, personal communication). Because the PICKIT program was developed for Egyptian broomrape management, our treatment regimens may simply have been initiated too early and the herbicide programs were not sufficiently persistent at the rates and timings used in this California experiment. A later start, longer intervals between timings, more timings, or higher application rates may improve performance.

Analysis of these data is ongoing. Although the efficacy results of a single field trial in one year were not clearcut, there were trends to suggest that, with some modifications, this approach may ultimately prove useful for management of branched broomrape in processing tomato in California. Future research is needed to evaluate best options to improve performance of the PICKIT programs for branched broomrape.