Broadleaf Weed Control in Safflower (*Carthamus tinctorius*) with Sulfonylurea Herbicides[1]

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Abstract. Safflower (*Carthamus tinctorius* L. 'Hartman') in the rosette growth stage or early bolting stage tolerated thiameturon {3-[[[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino] carbonyl] amino] sulfonyl] -2-thiophenecarboxylic acid} at 5, 10, and 15 g ai/ha. Safflower also tolerated chlorsulfuron {2-chloro-*N*-[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino] carbonyl] benzenesulfonamide} at 18 g/ha if safflower was taller than 15 cm at time of application. The fresh weight of above-ground biomass of common sunflower (*Helianthus annuus* L. #[3] HELAN), treated at two plant sizes with thiameturon, was reduced more than 88%. Soil activity of thiameturon also reduced the seedling vigor of common sunflower, but thiameturon in soil was not as lethal to common sunflower as were foliar applications.

Additional index words: *Helianthus annuus*, *Solanum triflorum*, chlorsulfuron, metsulfuron, thiameturon, canopy closure, HELAN, SOLTR.

INTRODUCTION

In the drier areas of the Central Great Plains, the predominant crop rotation is winter wheat – fallow – winter wheat. Because the shift from mechanical tillage to herbicides for weed control during the fallow period increases soil water storage (3, 4), a successful winter wheat – spring planted crop – fallow rotation is possible. Safflower, a deep-rooted crop adapted to the semiarid regions of the Western United States (6), is one spring crop suited for this 2-crop-in-3-yr rotation. When planted after winter wheat, saffflower grown under weed-free conditions yielded more than 2000 kg/ha in Colorado (1). Safflower was grown in Colorado, Nebraska, and Wyoming during the 1950s and 1960s (6), but inadequate weed management systems restricted successful safflower production and harvest.

Suitable herbicides for weed control in safflower, such as trifluralin [2,6-dinitro-*N*,*N*-dipropyl-4-(trifluoromethyl)benzenamine], were developed in the 1960s (7, 9). Trifluralin applied preplant incorporated controls most annual weeds in safflower, especially grasses, but does not adequately control certain broadleaf weeds, such as several mustard species (*Sinapis* spp.), common sunflower, Russian thistle (*Salsola iberica* Sennen & Pau # SASKR), and kochia [*Kochia scoparia* (L.) Schrad. # KCHSC]. Since these species hinder harvest operations and reduce grain yield in this safflower producing area, a herbicide to eliminate these broadleaf weeds is needed.

The sulfonylureas are a new class of herbicides which are active mainly on broadleaf weeds (5). One sulfonylurea herbicide, chlorsulfuron, when applied postemergence to safflower 15 to 20 cm tall, did not affect grain yields (1). However, safflower seedlings grow slowly after emergence and remain in a rosette growth form for 3 to 4 weeks. If broadleaf weeds emerge with the safflower seedlings, extensive weed growth could occur before safflower grows 15 cm tall and becomes tolerant to chlorsulfuron. Thus, an early postemergence herbicide treatment would ensure optimal safflower seedling growth without extensive weed competition. The objective of this study was to determine if sulfonylurea herbicides could be applied to safflower in the rosette growth stage without reducing grain yields.

MATERIALS AND METHODS

General procedures. The study was conducted over a 3-yr period at Akron, CO, on a Weld loam (fine montmorillinitic, mesic Aridic Paleustoll) composed of 35% sand, 43% silt, and 22% clay. The soil contained 1.2% organic matter and had a pH (1:1) of 6.4 to 6.8 in the top 5 cm. Nitrogen as ammonium nitrate was broadcast at 45 kg N/ha in April of each year before safflower planting. The plot area was disked twice to prepare the seedbed. A hoe drill was used to plant 'Hartman' safflower at 22 kg/ha, 2 to 4 cm deep, in rows spaced 30 cm

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[3] Letters following this symbol are a WSSA-approved computer code from Composite List of Weeds, Weed Sci. 32, Suppl. 2. Available from WSSA, 309 West Clark Street, Champaign, IL 61820.

apart. For all experiments, a randomized complete block experiment with four replications was used. Plot size was 4 by 6 m. The herbicides were applied in 245 L/ha with hollow cone nozzles in 1984 and 1985 and flat fan nozzles in 1986. A non-ionic adjuvant, allinol[4], at rates described in each of the studies, was added to the spray solutions of the sulfonylureas.

Sulfonylurea phytotoxicity to safflower. Saffflower was planted on May 11, 1984, April 22, 1985, and April 25, 1986. In 1984, chlorsulfuron at 18 g/ha was applied to safflower at three plant heights: 5 to 8 cm [rosette growth stage (10)] on June 12; 10 to 15 cm (early bolting growth stage) on June 21, and 20 to 25 cm (bolting growth stage) on June 28. In 1985, metsulfuron, {2-[[[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino] carbonyl] amino] sulfonyl] benzoic acid}, chlorsulfuron, and thiameturon were applied at 18 g/ha to safflower 10 to 15 cm tall (early bolting growth stage) on June 6. In 1986, thiameturon at 5, 10, and 15 g/ha was applied to safflower 5 to 10 cm (rosette growth stage) on May 21. The surfactant rate for all years was 0.5% v/v. To ensure weed-free conditions for all treatments, trifluralin at 1.1 kg ai/ha was applied and incorporated before planting. Weed escapes were removed by hand. The control consisted of safflower not treated with a sulfonylurea herbicide.

Plant injury was estimated visually 3 to 4 weeks after application of the sulfonylureas, using a rating scale of 0 to 100, with 0 = no injury and 100 = death of all plants. Plant height was recorded on July 9, 1984, 60 days before maturity, for the first study and at plant maturity in 1985 and 1986. Safflower was harvested from an area 1 by 3 m and was processed with a small plot thresher to determine grain yields. One hundred seeds were randomly selected from each grain sample to determine kernel weight in 1984 and percent germination in 1985 and 1986. The seeds were germinated for 14 days in petri dishes incubated without light in constant temperature chambers at 15 C to determine if herbicide treatment affected seed viability.

Safflower response to thiameturon in a weed-infested situation. Common sunflower was broadcast at 25 seeds/m^2 over the study area and was incorporated with a mulch treader on April 21, 1986. Safflower was planted on April 25. Thiameturon at 5, 10, and 15 g/ha with a surfactant rate of 0.12% v/v was applied to safflower 5 to 8 cm tall (rosette growth stage) on May 21. Plant height of common sunflower on the date of application was 5 to 10 cm. The control consisted of safflower infested with common sunflower but not sprayed with thiameturon. Visual weed control and common sunflower counts/m^2 were recorded on June 12, 22 days after application. Grain yields were determined by harvesting an area 1 by 3 m on September 3. Trifluralin at 1.1 kg/ha was applied preplant incorporated on April 21 to control grass weeds.

Thiameturon bioactivity on common sunflower. Studies were conducted to determine the foliar and soil activity of thiameturon on common sunflower. To examine foliar activity of thiameturon, common sunflower was planted at 25 seeds/m^2 on April 21, 1986. Seeds were broadcast and were incorporated with a mulch treader. Thiameturon at 5, 10, and 15 g/ha were applied to common sunflower at two plant sizes: 5 to 10 cm tall on May 21 and 20 to 25 cm tall on June 11. Two surfactant levels, 0.06 and 0.12% v/v, were included with all herbicide treatments. Three weeks after the herbicide application on each date, the above-ground biomass of all plants within a 1 m^2 quadrant in each plot was harvested, and fresh weight was recorded.

Thiameturon at 5, 10, or 15 g/ha was applied to a bare soil surface on May 21 and June 11 to examine soil activity of thiameturon. Soil samples 2.5 cm deep were collected randomly from each treated and nontreated plot 0, 7, 14, and 21 days after each herbicide application. Subsamples of 300 g of the collected soil were placed in 9-cm diam. by 9-cm deep plastic pots. Five common sunflower seeds were planted initially and were thinned to two plants per pot after emergence. The pots were watered daily and were incubated in a glasshouse with an average temperature of 25 ± 5 C. After 21 days of growth, the plants were harvested at the soil surface, and fresh weight of above-ground biomass was recorded. The data were analyzed as a factorial experiment with herbi-

[4] Activator 90, Loveland Industries, Inc., Loveland, CO 80537.

cide rate and sampling date as the main factor levels.

Effect of planting date on canopy closure of safflower. Safflower was planted on April 25, May 8, and May 22, 1986, to monitor the effect planting date has on the rate of canopy closure. The plots were observed weekly, and percent ground cover was estimated. Dates of emergence, bolting, and 100% canopy closure also were recorded. Canopy closure was defined as when the crop canopy completely covered the soil surface. An area 1 by 3 m was harvested on September 3 to determine grain yields.

RESULTS AND DISCUSSION

Sulfonylurea phytotoxicity to safflower. Safflower tolerance to chlorsulfuron increased with plant size (Table 1). Chlorsulfuron applied at 18 g/ha reduced grain yields only when safflower was 5 to 8 cm tall. Also, this application reduced plant height 39% and decreased plant vigor. Chlorsulfuron did not affect safflower growth when applied after safflower was 10 cm tall or greater.

When three sulfonylureas were applied at 18 g/ha to safflower 10 to 15 cm tall in 1985, only thiameturon was nontoxic to safflower (Table 2). Both metsulfuron and chlorsulfuron reduced plant height and grain yields, but metsulfuron was more injurious. Grain yields were reduced 48% by metsulfuron and 15% by chlorsulfuron. However, this reduction in crop vigor did not reduce germination of harvested seed (Table 2).

In 1986, thiameturon applied at 5, 10, and 15 g/ha to safflower in the rosette growth stage (5 to 10 cm tall) did not reduce plant height, grain yield, or seed germination (Table 3). Because of a severe drought in 1986, weed-free safflower yields were reduced 48 to 60% compared to weed-free safflower yields in 1984 or 1985. Precipitation was only 29% of normal in July and August of 1986. The results from these studies indicate that thiameturon can be applied safely postemergence to safflower 5 to 15 cm tall, whereas chlorsulfuron is suitable for postemergence applications when safflower is at least 15 cm tall.

Table 1. Agronomic response of safflower grown in 1984 at Akron, CO, to 18 g/ha of chlorsulfuron when applied at three plant heights.

Safflower height at time of spraying	Date of spray	Visible injury[a]	Plant height	Grain yield	100-kernel weight
(cm)		(%)	(cm)	(kg/ha)	(g)
5– 8	June 12	58	25.9	1280	2.7
10–15	June 21	6	39.9	1560	2.9
20–25	June 28	0	44.5	1730	2.8
Control	...	0	42.7	1810	2.7
LSD (0.05)		14	5.3	410	NS

[a]Visible injury rating scale was 100% = total plant kill and 0% = no visible plant injury.

Table 2. Agronomic response of safflower grown in 1985 at Akron, CO, to three sulfonylurea herbicides when applied to safflower 10 to 15 cm in height.

Treatment	Rate	Visible injury[a]	Plant height	Grain yield	Germination
	(g/ha)	(%)	(cm)	(kg/ha)	(%)
Metsulfuron	18	25	46.3	1230	83
Chlorsulfuron	18	18	56.0	2020	81
Thiameturon	18	2	61.3	2320	92
Control	...	0	63.0	2380	81
LSD (0.05)		6	2.5	290	8

[a]Visible injury rating scale was 100% = total plant kill and 0% = no visible plant injury.

Safflower response to thiameturon in a weed-infested situation. Thiameturon at 5, 10, and 15 g/ha controlled common sunflower 96 to 99% (Table 3). Thiameturon had no apparent activity on cutleaf nightshade (*Solanum triflorum* Nutt. # SOLTR) (data not shown). The cutleaf nightshade population was too uneven to reliably estimate its response to the thiameturon treatments. Safflower grain yields did not differ among herbicide treatments (Table 3). Comparing these grain yields of weed-infested safflower with grain yields of weed-free safflower grown adjacent to this study (Table 3) shows that interference by common sunflower for 14 days after safflower emergence (May 7 to May 21, date of spray) was not detrimental to safflower grain yields. However, season-long interference from common sunflower reduced safflower yield 93% compared to the yield of the weed-free control.

Thiameturon bioactivity on common sunflower. Common sunflower was very susceptible to foliar applications of thiameturon (Table 4). Above-ground fresh weight of common sunflower was reduced by more than 97% when treated with thiameturon

Table 3. Effect of thiameturon on safflower grown in weed-free and weed-infested conditions in 1986 at Akron, CO. Safflower was 5 to 10 cm tall when thiameturon was applied.

		Weed-free safflower				Weed-infested safflower			
						Control of common sunflower		Safflower response	
Herbicide treatment	Rate	Visible injury[a]	Plant height	Grain yield	Germination	Visible[b]	Counts	Plant height	Grain yield
	(g/ha)	(%)	(cm)	(kg/ha)	(%)	(%)	(no./m²)	(cm)	(kg/ha)
Thiameturon	5	2	76.2	1020	77	96	3.3	76.2	970
Thiameturon	10	0	74.4	970	80	98	2.0	76.0	1020
Thiameturon	15	2	76.2	1000	86	99	0.9	76.2	1000
Weed-free control	...	0	77.0	950	80	...	...	...	...
Weed-infested control	...	...	...	...	...	0	19.3	80.0	70
LSD (0.05)		NS	NS	NS	NS	6	3.0	NS	250

[a]Visible injury rating scale was 100% = total plant kill and 0% = no visible plant injury.

[b]Visible weed control scale was 100% = plot area weed free and 0% = plot area completely weed infested.

at the 5- to 10-cm plant height. When common sunflower was 20 to 25 cm tall at the time of application, thiameturon reduced above-ground biomass by more than 88%. Surfactant level did not influence thiameturon activity. Also, there was no regrowth of treated plants from either date of application. Because thiameturon controls relatively large common sunflower, the producer has more flexibility in timing the thiameturon application.

Thiameturon applied to bare soil did not kill common sunflower seedlings emerging after application (Table 5). Thiameturon at 15 g/ha reduced seedling growth only 18 to 32% over all sampling dates. These results indicate that common sunflower which emerge after thiameturon application will be stunted slightly, but the seedlings will survive. Because thiameturon applied postemergence controls large common sunflower, its application could be timed to allow the majority of common sunflower seedlings to emerge before spraying.

Effect of planting date on canopy closure of safflower. Safflower remains in a rosette growth stage for 3 to 4 weeks after emergence, but the duration of this growth stage can be influenced by daylength and temperature (10). Altering the planting date would change the daylength and early season temperature, possibly reducing the duration of this rosette growth form. After bolting, branching is rapid, the canopy closes, and safflower becomes more competitive against weeds due to increased shading.

In this study, however, planting date did not influence the duration of the rosette growth stage, which still varied from 3 to 4 weeks (Figure 1).

Table 4. Common sunflower response to three rates of thiameturon and two rates of surfactant when applied at two plant heights.

			Common sunflower fresh weight	
			Plant height at application	
Herbicide treatment	Rate	Surfactant rate	5–10 cm	20–25 cm
	(g/ha)	(%)	(g/m²)	
Thiameturon	5	0.06	17	300
Thiameturon	10	0.06	13	320
Thiameturon	15	0.06	1	230
Thiameturon	5	0.12	35	260
Thiameturon	10	0.12	1	220
Thiameturon	15	0.12	4	190
Control	...	...	1390	2650
LSD (0.05)			80	170

Table 5. Soil activity of thiameturon on common sunflower seedling growth.

Thiameturon rate	Days after application				Mean
	0	7	14	21	
(g/ha)	(% growth inhibition)[a]				
5	11	18	12	1	11
10	15	23	13	6	14
15	26	32	19	18	24
Mean	17	24	15	8	

LSD (0.05) thiameturon levels = 9.
LSD (0.05) days after application levels = 11.
LSD (0.05) interaction = NS.

[a]Treatment means are the average of two studies.

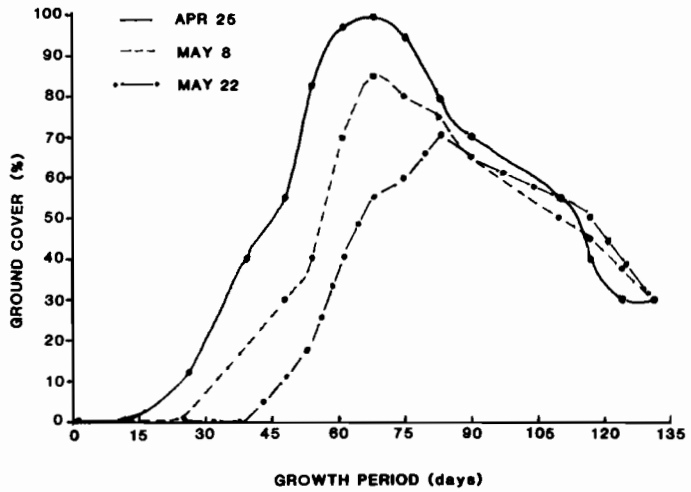

Figure 1. The development of percent ground cover of safflower as influenced by three planting dates. Observation of growth was initiated on May 6, 1986.

However, planting date did affect canopy closure. Safflower planted on May 8 or May 22 did not develop 100% canopy closure, thus being less competitive with weeds than the April 25 planting of safflower which developed a full canopy cover (Figure 1). Also, delayed planting reduced grain yield; safflower yields were 1260, 1170, and 930 kg/ha when planted on April 25, May 8, and May 22, 1986, respectively.

The prevalent use of trifluralin for weed control in safflower has allowed common sunflower to become a serious weed problem in this crop. Common sunflower usually emerges in late May and early June in the Central Great Plains (8). Thiameturon applied in mid-June would control early season common sunflower until the safflower canopy closed, providing safflower producers with a control option for these early season broadleaf weeds.

Senescence of lower leaves after safflower flowering increases light penetration to the soil surface (Figure 1). If sufficient rainfall occurs, late-emerging broadleaf weeds, such as kochia and Russian thistle, become established and interfere with crop harvest (personal observation). Chlorsulfuron applied in late season will control these weeds (1). Because chlorsulfuron persists in the soil for an extended time, its application will also control certain broadleaf weeds during fallow in the Central Great Plains (2). The availability of thiameturon and chlorsulfuron should help to develop successful broadleaf weed management systems for safflower production in the Central Great Plains.

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