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Chlorsulfuron for Weed Control in Safflower (*Carthamus tinctorius*)[1]

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Abstract. **Chlorsulfuron {2-chloro-*N*-[[(4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino] carbonyl] benzenesulfonamide} was nontoxic to safflower (*Carthamus tinctorius* L.) when applied postemergence in 1983 and 1984 at 0.018 and 0.035 kg ai/ha. Trifluralin [2,6-dinitro-*N,N*-dipropyl-4-(trifluoromethyl)benzenamine] at 1.1 and 1.7 kg ai/ha and pronamide [3,5-dichloro(*N*-1,1-dimethyl-2-propynyl)benzamide] at 0.8 and 1.1 kg ai/ha were applied previously as preplant soil-incorporated treatments. In both years, safflower was relatively free of weeds where trifluralin was applied alone or in sequential treatments with chlorsulfuron. Pronamide, with or without chlorsulfuron, failed to completely control witchgrass (*Panicum capillare* L. #[3] PANCA) in 1 yr; thus safflower grain yields were reduced 21 to 35% when compared to weed-free safflower. Chlorsulfuron controlled redroot pigweed (*Amaranthus retroflexus* L. # AMARE), puncturevine (*Tribulus terrestris* L. # TRBTE), and common sunflower (*Helianthus annuus* L. # HELAN).**

Additional index words. **Phytotoxicity, germination, *Panicum capillare, Amaranthus retroflexus, Tribulus terrestris, Helianthus annuus*, PANCA, AMARE, TRBTE, HELAN.**

INTRODUCTION

Safflower is a deep-rooted crop adapted to the semiarid regions of the western U.S.A., having been grown in Colorado, Nebraska, and Wyoming in the 1950's and 1960's (4). Once established, it withstands periods of drought longer than other annual crops[4] and is very tolerant of high temperatures. Dry atmospheric conditions during and after flowering are necessary for proper seed set, high grain yields, and high oil content (4). These atmospheric conditions are prevalent in the Central Great Plains.

Safflower seedlings grow slowly, remaining in a rosette growth form for 3 to 4 weeks after emergence. During this period, safflower is a poor weed competitor, but after the rosette stage, plants elongate rapidly, branch extensively, and are more competitive with weeds[4]. Weed control during the rosette period is essential for safflower production. Inadequate weed management systems during the 1950's and 1960's restricted successful safflower production and harvesting. With the development of suitable herbicides in the 1960's and 1970's, safflower production became feasible. Herbicides presently used for weed control in safflower include trifluralin and pronamide (1, 5, 8).

Trifluralin has been the principal herbicide used for weed control in safflower. Trifluralin controls most annual weeds in safflower, especially grasses, but does not adequately control several mustard species (*Sinapis* spp.) and common sunflower[4]. Also, Russian thistle (*Salsoli kali* L. var. *tenuifolia* Tausch. # SASKA) and kochia (*Kochia scoparia* L. # KCHSC) occasionally escape herbicide control, and their resultant growth greatly hinders harvest operations and reduces grain yield. While causing no injury to safflower (8), pronamide is toxic to grass seedlings but does not control broadleaf weeds.

Chlorsulfuron is a recently released sulfonylurea, a new class of herbicides (2). It selectively controls broadleaf weeds in small grains (7) and is registered for use in wheat (*Triticum aestivum* L.) and barley (*Hordeum vulgare* L.). Late postemergence applications of chlorsulfuron have been shown to be safe on safflower in North Dakota[5]. Chlorsulfuron may have the potential to eliminate broadleaf weeds that are not controlled by soil-applied trifluralin or pronamide, thus ensuring safflower production and reducing harvesting difficulties. The objective of this study was to determine if chlorsulfuron could be used in combination with these herbicides for an effective weed management system for safflower.

MATERIALS AND METHODS

'Hartman' safflower was planted with a hoe drill in rows spaced 30.5 cm apart at 22 kg/ha on April 29, 1983, and May 11, 1984, at Akron, CO. The soil type was a Weld loam (fine montmorillinitic, mesic Aridic Paleustolls) composed of 38% sand, 39% silt, and 23% clay. The soil contained 1.3% organic matter and the pH was 6.5. Nitrogen was applied at 50 kg/ha in April of each year before planting. The available stored soil water to a depth of 1.8 m was 19.2 cm in 1983 and 25.4 cm in 1984.

Trifluralin and pronamide were applied on April 28, 1983, and May 10, 1984, with a tractor-mounted sprayer equipped with hollow-cone nozzles on a 4-m boom. The herbicides were applied in 144 L/ha of spray solution at 448 kPa and incorporated with a tandem disk and mulch treader to a depth of 10 cm. Chlorsulfuron was applied postemergence on July 1, 1983, and June 26, 1984, to safflower 15 to 20 cm high. The experimental design for this study was a split-block design (also known as strip-plot) as described by Little and Hills (3). The main treatments, trifluralin at 1.1 and 1.7 kg ai/ha and pronamide at 0.8 and 1.1 kg ai/ha and two controls, weed-infested and weed-free, were arranged

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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 St., Champaign, IL 61820.

[4]Bergman, J. W., G. P. Hartman, A. L. Black, P. L. Brown, and N. R. Riveland. 1979. Safflower production guidelines. Montana Agric. Exp. Stn., Capsule Info. Series 8:1–25.

[5]Postemergence weed control in safflower. 1982. North Dakota Weed Control Res.; Weed Res. Project, Dep. Agron., North Dakota State Univ. Pages 44–46.

in a randomized complete block design with three replications. The subunit treatments, chlorsulfuron at 0.0, 0.018, and 0.035 kg/ha, were applied in continuous strips across the entire block of main plots and were independently randomized in each replication. The main plot size was 4 m wide by 12 m long, while the subunit plot size was 4 m wide by 4 m long. The weed-free control treatment was handweeded as needed to eliminate competition from emerging weeds.

Herbicide performance was assessed 3 weeks after chlorsulfuron was applied by recording the number of weeds present in three, 1-m^2 quadrates randomly placed in each plot. Crop tolerance was assessed visually, using a rating scale of 0 to 100, with 0 = no injury and 100 = death of all plants. Other data taken included the date when at least 50% of the plants had flowered, plant height at maturity, grain yields, and 100-kernel weight. Safflower was harvested from an area 1.5 m by 4 m in 1983 and 1 m by 3 m in 1984. One hundred safflower seeds were collected from each treatment at harvest and were germinated without light in petri dishes incubated at 15 C in constant temperature chambers to determine if seed viability was affected by herbicide treatments. Data were subjected to an analysis of variance separately for each year, and differences between means were determined at the 5% level of significance using Duncan's multiple range test (6).

RESULTS AND DISCUSSION

Weed population varied in the two cropping seasons, with the level of weed infestation being greatest in 1984. For example, there were 15 times more witchgrass plants in 1984 than in 1983 (Tables 1 and 2). Thus, results from each year are presented and discussed separately. Also, since there was not a significant herbicide rate effect, the data presented are the average of all rates within that treatment.

1983 study. In 1983, chlorsulfuron reduced the number of puncturevine and redroot pigweed when applied alone or sequentially to pronamide, but applied alone, chlorsulfuron showed no activity on witchgrass (Table 1). Pronamide applied alone also failed to control witchgrass, but when it was combined with chlorsulfuron, the witchgrass population was reduced 39% compared to the weed-infested control. Trifluralin applied alone or in combination with chlorsulfuron resulted in essentially weed-free safflower.

Due to little weed competition in 1983, any crop response significantly reduced below that of the weed-free control by a herbicide treatment would be the result of herbicide damage. However, no differences in crop response were detected among any herbicide treatments except for pronamide. Grain yield loss from the pronamide treatments was attributed to the redroot pigweed and witchgrass competition. The grain yield and plant height following all other herbicide treatments were the same as the weed-free control. Also, no herbicide injury was visually observed, and the date of flowering was the same for all treatments (data not presented). Seed weight and germination were also not affected by herbicide treatment, further indicating that chlorsulfuron was not phytotoxic to safflower (Table 1).

1984 study. In 1984, when the witchgrass infestation was more severe, pronamide significantly reduced the number of witchgrass plants per m^2 compared to the weed-infested control, yet 6.2 plants/m^2 remained in the treated areas (Table 2). Chlorsulfuron applied alone reduced the stand of witchgrass by approximately 50% compared to the weed-infested control. The remaining witchgrass infestation in the chlorsulfuron-alone treatments was 17.0 plants/m^2, however, and significantly reduced grain yields. Chlorsulfuron eliminated all broadleaf weeds when applied sequentially with pronamide, but grain yields were decreased by the remaining witchgrass infestation. Trifluralin effectively controlled all weeds present in 1984, whether applied alone or in combination with chlorsulfuron.

Phytotoxicity to safflower was not detected with any herbicide treatment. Visual injury or delay in date of flowering was not observed with any treatment (data not presented). The herbicide treatments that reduced grain yield compared to the weed-free control were pronamide and chlorsulfuron,

Table 1. Weed control and crop response with chlorsulfuron, pronamide, and trifluralin in safflower (1983). The values for each herbicide treatment are averages of all rates for that treatment[a].

Treatment	Weed control[b]			Crop response[b]			
	Puncturevine	Redroot pigweed	Witchgrass	Plant height	Grain yields	100-kernel weight	Grain germination
	(plants/m^2)			(cm)	(kg/ha)	(g)	(%)
Chlorsulfuron	0.3 b	0.2 b	2.5 a	66 a	1660 ab	2.5 a	86 a
Pronamide	0.4 b	1.7 b	2.4 a	67 a	1490 b	2.5 a	85 a
Chlorsulfuron + pronamide	0.3 b	0.3 b	1.2 ab	68 a	1720 a	2.5 a	84 a
Trifluralin	0.0 b	0.0 b	0.0 b	67 a	1810 a	2.4 a	83 a
Chlorsulfuron + trifluralin	0.0 b	0.0 b	0.0 b	67 a	1700 a	2.5 a	83 a
Control (weed-free)	0.0 b	0.0 b	0.0 b	66 a	1720 a	2.5 a	87 a
Control (weed-infested)	2.3 a	6.0 a	2.3 a	66 a	960 c	2.3 a	80 a

[a]The rates were 0.018 and 0.035 kg/ha for chlorsulfuron, 0.8 and 1.1 kg/ha for pronamide, and 1.1 and 1.7 kg/ha for trifluralin. The combination treatments include all possible combinations.

[b]Values in a column followed by the same letter are not significantly different at the 5% level as determined by Duncan's multiple range test.

Table 2. Weed control and crop response with chlorsulfuron, pronamide, and trifluralin in safflower (1984). The values for each herbicide treatment are averages of all rates for that treatment[a].

Treatment	Weed control[b]			Crop response[b]			
	Common sunflower	Redroot pigweed	Witchgrass	Plant height	Grain yields	100-kernel weight	Grain germination
	(plants/m²)			(cm)	(kg/ha)	(g)	(%)
Chlorsulfuron	0.0 b	0.0 b	17.0 b	68 a	1230 c	2.9 a	87 a
Pronamide	0.4 b	1.1 a	6.2 c	67 ab	1440 bc	2.8 a	85 a
Chlorsulfuron + pronamide	0.0 b	0.0 b	4.6 c	66 ab	1600 b	2.8 a	84 a
Trifluralin	0.0 b	0.0 b	0.0 d	67 ab	2140 a	2.8 a	85 a
Chlorsulfuron + trifluralin	0.0 b	0.0 b	0.2 d	69 a	2290 a	2.8 a	85 a
Control (weed-free)	0.0 b	0.0 b	0.0 d	68 a	2170 a	2.9 a	87 a
Control (weed-infested)	1.0 a	2.0 a	35.0 a	64 b	490 d	2.6 b	84 a

[a]The rates were 0.018 and 0.035 kg/ha for chlorsulfuron, 0.8 and 1.1 kg/ha for pronamide, and 1.1 and 1.7 kg/ha for trifluralin. The combination treatments include all possible combinations.

[b]Values in a column followed by the same letter are not significantly different at the 5% level as determined by Duncan's multiple range test.

each alone and in combination. This yield loss was attributed to witchgrass competition. Grain yields were similar to the weed-free control in all plots treated with trifluralin. The herbicide treatments did not affect seed formation, since no differences occurred with 100-kernel weight or seed germination for any treatment (Table 2). As in 1983, chlorsulfuron applied postemergence to safflower at 15- to 20-cm plant height was not injurious to safflower.

Weed management systems for safflower. Trifluralin resulted in relatively weed-free safflower, thus demonstrating its effectiveness for weed control in safflower. Pronamide failed to completely control witchgrass, which is probably explained by the rapid degradations of pronamide when soil temperatures increase in early summer (9). This is the period when witchgrass, a warm season annual, initiates growth. Thus, pronamide would fail to control the later germinating grasses present in the Central Great Plains and would be ineffective for grassy weed control in safflower grown in this area. Chlorsulfuron adequately controlled the broadleaf weeds present in this study and was not injurious to the safflower when applied alone or in combination with either preplant-incorporated herbicide. Thus, in the production of safflower, if broadleaf weeds escape trifluralin control or are not controlled by other preplant-incorporated herbicides that have activity on only grassy weeds, chlorsulfuron could be applied postemergence to control the broadleaf weeds. The decision to apply chlorsulfuron could thus be made during the growing season, and it could be applied only to areas in the field where broadleaf weeds are present. Also, these results suggest possible future research where chlorsulfuron could be evaluated for weed control in no-till planted safflower, where postemergence herbicides can be used for grassy weed control.

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