Tolerance of Hooker's Evening Primrose Transplants to Preemergence Herbicides

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SUMMARY. **No research has investigated the phytotoxic response of hooker's evening primrose (*Oenothera elata*) plug transplants to preemergence herbicides. Varied phytotoxic responses of common evening primrose (*Oenothera biennis*) to preemergence herbicides suggest that options may exist for the safe control of weeds present within hooker's evening primrose when grown as an agronomic field crop. Enhanced weed control during early establishment may reduce competition for water and nutrients as well as increase seed yield and oil content. Therefore, the objective of this research was to determine the phytotoxic effect of preemergence herbicides on hooker's evening primrose plug transplants grown in the greenhouse. Research was conducted in 2010 and 2011 at the Plant and Soil Science greenhouse complex at Texas Tech University in Lubbock, TX. Herbicide treatments were applied on 13 July 2010 and 5 Apr. 2011 and consisted of oxadiazon at 3 lb/acre, isoxaben at 0.5 lb/acre, oryzalin at 2 lb/acre, prodiamine at 1.5 lb/acre, dithiopyr at 0.5 lb/acre, s-metolachlor at 1.8 lb/acre, pendimethalin at 0.6 lb/acre, and isoxaben + trifluralin at 2.5 lb/acre. One 4-month-old hooker's evening primrose plug (2 inches wide) was transplanted into each pot (3 gal) 2 days after treatment (DAT). Dithiopyr and s-metolachlor treatments exhibited similar lack of phytotoxicity as the untreated control 7 DAT. Phytotoxicity ≥13% was observed for trifluralin + isoxaben, pendimethalin, prodiamine, oryzalin, isoxaben, and oxadiazon 7 DAT, with the highest level of phytotoxicity (24%) exhibited by trifluralin + isoxaben treatments. Hooker's evening primrose phytotoxicity decreased (plants grew out of the damage) for all treatments except trifluralin + isoxaben, pendimethalin, and oryzalin 28 DAT. Oryzalin (16%) and trifluralin + isoxaben (60%) were the only two treatments that did not exhibit similar phytotoxicity to the untreated control 28 DAT. There were no significant differences in aboveground or belowground biomass nor plant growth index (PGI) of any of the treatments when compared with the untreated control 28 DAT. Based upon the results of this trial, pendimethalin, prodiamine, dithiopyr, s-metolachlor, oryzalin, isoxaben, and oxadiazon may be used for preemergence weed control in hooker's evening primrose without causing excessive phytotoxicity (>20%), potential yield loss, or both. Trifluralin + isoxaben treatments exhibited 60% hooker's evening primrose phytotoxicity 28 DAT, which resulted in too low of an initial plant stand to warrant use.**

Hooker's evening primrose is a biennial to short-lived perennial native to areas as far north as Oregon, south as Panama, east as Texas, and west as coastal California (Dietrich et al., 1997). Plants are often found in full sun along streams and rocky slopes as well as in meadows and disturbed areas (Arnold, 2008; Dietrich et al., 1997). Hooker's evening primrose shoots (1.5 to 8 ft tall) emerge from the center of a basal rosette at about the 20- to 50-leaf stage (Dietrich et al., 1997; Harte, 1994). Leaves are dull green to gray-green with bluntly dentate or subentire margins (Dietrich et al., 1997). Showy yellow flowers (1.2 to 1.4 inches wide) usually only occur once at sunrise or sunset during periods of long days and short nights (Correll and Johnston, 1970; Dietrich et al., 1997; Harte, 1994). Flowers are pollinated by hawk moths (family Sphingidae) and give rise to seed capsules measuring 0.8 to 2.6 inches long (Dietrich et al., 1997). Each capsule splits in four places and may contain up to 500 seeds (Harte, 1994).

Drought tolerance and floral attributes of hooker's evening primrose have led to its use as an ornamental plant in xeriscapes throughout arid and semiarid regions of the United States (Arnold, 2008). High levels of γ-linolenic acid, an omega-3 fatty acid essential for human metabolism, present in seed oil has further increased interest in the cultivation of this plant as an agronomic crop (Balch et al., 2003). However, because of poor field germination, hooker's evening primrose must first be propagated in the greenhouse and transplanted into the field following maturation to the rosette stage (Murphy et al., 1999).

The presence of weeds in agricultural fields often increases the time and costs of crop production as well as reduces crop yields and quality (Anderson, 1996). Bridges (1992) estimated that the average annual monetary loss because of weed competition in 46 U.S. grown crops was $4.1 billion in 1991. Losses are directly proportionate to the amount of light, water, and nutrients that weeds intercept from the agronomic crops they infest (Buchanan and Burns, 1970). The critical weed free period for many crops exists during early establishment. The critical weed free period for sorghum (*Sorghum bicolor*), beet (*Beta vulgaris*), and field bean (*Phaseolus vulgaris*) to prevent yield loss is 4, 9 to 12, and 5 to 7 weeks, respectively (Burnside and Wicks, 1967; Dawson, 1964, 1965). Early critical weed-freeperiods and phytotoxicity concerns associated with many postemergence herbicides make preemergence herbicide applications even more important.

Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
0.3048	ft	m	3.2808
3.7854	gal	L	0.2642
9.3540	gal/acre	$L\cdot ha^{-1}$	0.1069
2.54	inch(es)	cm	0.3937
1.1209	lb/acre	$kg\cdot ha^{-1}$	0.8922
28.3495	oz	g	0.0353
6.8948	psi	kPa	0.1450
(°F – 32) ÷ 1.8	°F	°C	(°C × 1.8) + 32

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Few research trials have focused on the phytotoxic effect of preemergence herbicides on evening primrose species. Richardson and West (1986) observed no reduction in common evening primrose fresh shoot weight grown from seed 42 DAT in response to isoxaben (0.075 $kg \cdot ha^{-1}$) and trifluralin (1.0 and 2.0 $kg \cdot ha^{-1}$). However, applications of simazine (0.25 and 0.5 $kg \cdot ha^{-1}$), chlorsulfuron (0.01 and 0.02 $kg \cdot ha^{-1}$), and metsulfuron (0.00375 and 0.0075 $kg \cdot ha^{-1}$) were lethal to common evening primrose at 42 DAT. Stringer et al. (1985) reported 91% to 100% survival of seeded common evening primrose at 68 DAT in response to trifluralin (0.8 $kg \cdot ha^{-1}$), EPTC (2.0 $kg \cdot ha^{-1}$), propachlor (4.0 $kg \cdot ha^{-1}$), and linuron (0.25 $kg \cdot ha^{-1}$). However, when applied at a higher rate, linuron (1.0 $kg \cdot ha^{-1}$) and lenacil (0.5 and 2.0 $kg \cdot ha^{-1}$) reduced common evening primrose survival below 9% at 68 DAT.

No research has investigated the phytotoxic response of hooker's evening primrose plug transplants to preemergence herbicides. Varied phytotoxic responses of common evening primrose to preemergence herbicides suggest that options may exist for the safe control of weeds present within hooker's evening primrose when grown as an agronomic field crop. Enhanced weed control during early establishment may reduce competition for water and nutrients as well as increase seed yield and oil content. Therefore, the objective of this research was to determine the phytotoxic effect of preemergence herbicides on hooker's evening primrose plug transplants grown in the greenhouse.

Materials and methods

Experiments were conducted in 2010 and 2011 at the Plant and Soil Science greenhouse complex at Texas Tech University in Lubbock, TX. Pots (3 gal) were filled with a Brownfield sandy clay loam (Loamy, mixed, superactive, thermic Arenic Aridic Paleustalfs) with a pH of 8.1 and organic matter content of 1.4%. The trial was arranged in a randomized complete block design with five replications. Herbicide treatments were applied on 13 July 2010 and 5 Apr. 2011 and consisted of oxadiazon (Ronstar FLO; Bayer Environmental Science, Research Triangle Park, NC) at 3.0 lb/acre, isoxaben (Gallery; Dow AgroSciences, Indianapolis, IN) at 0.5 lb/acre, oryzalin (Surflan; United Phosphorous, King of Prussia, PA) at 2.0 lb/acre, prodiamine (Barricade; Syngenta Professional Products, Greensboro, NC) at 1.5 lb/acre, dithiopyr (Dimension, Dow AgroSciences) at 0.5 lb/acre, s-metolachlor (Pennant Magnum, Syngenta Professional Products) at 1.8 lb/acre, pendimethalin (Pendulum; BASF Specialty Products, Research Triangle Park, NC) at 0.6 lb/acre, and isoxaben + trifluralin (Snapshot, Dow AgroSciences) at 2.5 lb/acre. An untreated control was included for comparison. Preemergence herbicide application rates were chosen based on label recommendations for similar crops and transplant size. Treatments were applied using a carbon dioxide-pressurized backpack sprayer equipped with 8004VS nozzles (extended range flat spray tips; TeeJet Technologies, Wheaton, IL) calibrated to deliver 40 gal/acre at 32 psi. One 4-month-old hooker's evening primrose plug (≈2 inches wide) was transplanted into each pot 2 DAT. A single plug was used per pot to avoid negative impacts from plant competition and/or root distribution within the pot. Slow release fertilizer (14N–6.1P–11.6K, Osmocote; Scotts, Marysville, OH) was applied at the time of transplant at a rate of 43 lb/acre nitrogen. Greenhouse temperatures were maintained at 93/79 °F (day/night) with average midday (1200 and 1300 HR) solar radiation ranging from 636 to 754 $\mu mol \cdot m^{-2} \cdot s^{-1}$. Irrigation was supplied through an overhead irrigation system calibrated to deliver ≈1.5 inches of water per week.

Data collected included hooker's evening primrose phytotoxicity, biomass measurements, and PGI. Phytotoxicity was evaluated 7 and 28 DAT on a scale of 0 (no hooker's evening primrose phytotoxicity) to 100% (complete plant death). Plants exhibiting 25% phytotoxicity were slightly stunted and had minor leaf tip burn and leaf chlorosis, while plants exhibiting 50% phytotoxicity were stunted, chlorotic, slightly necrotic, and exhibited epinasty/stem collapse. Plants were destructively harvested 28 DAT in both experiments. Plants were divided into shoots and roots, dried, and weighed to determine above- and belowground biomass (grams). Plant height and two plant widths (perpendicular to each other) were recorded 28 DAT to calculate PGI. PGI was calculated by averaging the plant height and two plant widths according to Behandary et al. (1997).

Hooker's evening primrose phytotoxicity, biomass measurements, and PGI measurements were arcsine square-root transformed to stabilize variance (Ahrens et al., 1990) before being subjected to analysis of variance in SAS (version 9.3; SAS Institute, Cary, NC), with main effects and all possible interactions tested using the appropriate expected mean square values described by McIntosh (1983). Interpretations were not different from nontransformed data; therefore, nontransformed means are presented for clarity. No significant run-by-treatment interactions were detected so data were combined. All data were subjected to analysis of variance in SAS using the appropriate expected mean square values described by McIntosh (1983). Treatment means were separated using Fisher's protected least significant difference test at $\alpha = 0.05$.

Results and discussion

Dithiopyr and s-metolachlor treatments exhibited similar lack of phytotoxicity as the untreated control 7 DAT (Table 1). Derr (1993) observed similar phytotoxicity (0% to 12%) 2 weeks after treatment (WAT) to transplants of lanceleaf coreopsis (*Coreopsis lanceolata*), ox-eye daisy (*Chrysanthemum leucantheum*), blanket flower (*Gaillardia aristata*), and purple coneflower (*Echinacea purpurea*) in response to metolachlor at 4.5 and 9.0 $kg \cdot ha^{-1}$. Phytotoxicity ≥13% was observed for trifluralin + isoxaben, pendimethalin, prodiamine, oryzalin, isoxaben, and oxadiazon 7 DAT, with the highest level of phytotoxicity (24%) exhibited by trifluralin + isoxaben treatments.

Hooker's evening primrose phytotoxicity decreased (plants grew out of the initial damage) for all treatments except trifluralin + isoxaben, pendimethalin, and oryzalin 28 DAT (Table 1). Oryzalin (16%) and trifluralin + isoxaben (60%) were the only two treatments that did not exhibit similar phytotoxicity to the untreated control 28 DAT. Similar phytotoxicity (2.1 to 2.6 on a scale of

Table 1. Response of hooker's evening primrose transplants to preemergence herbicides in the greenhouse in Lubbock, TX. Data were pooled across experimental runs.

Treatment	Rate (lb/acre)[z]	7 DAT[y]	28 DAT	Aboveground	Belowground	PGI[w]
		Phytotoxicity (%)[x]		Biomass (g)[z]		
Untreated control	—	0	0	0.53	0.29	10.9
Trifluralin + isoxaben	2.5	24	60	0.27	0.19	6.5
Pendimethalin	0.6	13	13	0.58	0.17	10.6
Prodiamine	1.5	15	6	0.57	0.25	11.1
Dithiopyr	0.5	8	4	0.63	0.23	12.5
S-metolachlor	1.8	12	9	0.41	0.2	9.1
Oryzalin	2.0	14	16	0.26	0.23	7.1
Isoxaben	0.5	13	7	0.54	0.21	11.7
Oxadiazon	3.0	15	10	0.39	0.21	8.1
$LSD_{0.05}$[v]		12	15	0.34	0.15	5.4

[z]1 lb/acre = 1.1209 kg·ha^{-1}, 1 g = 0.0353 oz.
[y]Days after treatment.
[x]Phytotoxicity was evaluated on a scale of 0% (no hooker's evening primrose phytotoxicity) to 100% (complete plant death). Plants exhibiting 25% phytotoxicity were slightly stunted and had minor leaf tip burn and leaf chlorosis, while plants exhibiting 50% phytotoxicity were stunted, chlorotic, slightly necrotic, and exhibited epinasty/stem collapse.
[w]Plant growth index was calculated by averaging the plant height and two plant widths according to Behandary et al. (1997).
[v]Fisher's protected least significant difference at $P \leq 0.05$.

1 = no injury to 5 = dead plant) was observed on 'Vodka' begonia (*Begonia semperflorens-cultorum*) and 'Fireball' salvia (*Salvia splendens*) 30 DAT in response to trifluralin + isoxaben at 3.4 kg·ha^{-1} (Thetford et al., 1995). Pendimethalin, prodiamine, dithiopyr, s-metolachlor, isoxaben, and oxadiazon all exhibited ≤13% hooker's evening primrose phytotoxicity 28 DAT. Gilreath et al. (2008) observed similar phytotoxicity of four-true-leaf leek (*Allium porrum*) transplants to pendimethalin (11%) at 1.1 kg·ha^{-1}, but greater phytotoxicity in response to metolachlor (38%) at 2.3 kg·ha^{-1} and prodiamine (18%) at 1.7 kg·ha^{-1} 4 weeks after planting.

There were no significant differences in above- or belowground biomass of any of the treatments when compared with the untreated control 28 DAT (Table 1). Neal and Senesac (1990) reported no reduction in aboveground biomass of stock plant division transplants of 'Albomarginata' plantain lily (*Hosta lancifolia*) 92 d after initial treatment in response to sequential applications of isoxaben (1.1 kg·ha^{-1}), oryzalin (4.5 kg·ha^{-1}), and trifluralin + isoxaben (4.24 kg·ha^{-1}). Derr and Salihu (1996) observed similar belowground biomass results (0.4 to 0.9 g) on 'Edward Goucher' abelia (*Abelia ×grandiflora × A. Schumannii*) 5 weeks after sequential application of oxadiazon (4.48 kg·ha^{-1}), isoxaben (1.12 kg·ha^{-1}), and oryzalin (4.48 kg·ha^{-1}) compared with the untreated control (1.4 g). No significant differences in PGI were detected for any of the treatments when compared with the untreated control 28 DAT (Table 1).

Methods employed in this research may have increased the incidence of hooker's evening primrose phytotoxicity compared with trials conducted in the field. Plants grown under greenhouse conditions are often more susceptible to herbicides, and therefore exhibit higher levels of phytotoxicity. Coffman and Gentner (1980) reported 68% and 30% italian ryegrass (*Lolium multiflorum*) phytotoxicity 1 WAT in response to trifluralin at 1.1 kg·ha^{-1} when applied in the field and greenhouse, respectively. Transplant size may also have an effect on herbicide phytotoxicity. Hooker's evening primrose transplants used in our research were 2 inches wide when herbicides were applied. Larger transplants may have reduced herbicide phytotoxicity. Derr and Salihu (1996) reported that a decrease in efficacy of several preemergence herbicides on redtip photinia (*Photinia ×fraserii*), 'Tradition' azalea (*Rhododendron obtusum*), abelia (*Abelia grandiflora × A. Schumannii*), and 'Helleri' japanese holly (*Ilex crenata*) may have been caused by an increase in plant size. Miller et al. (2003) observed greater yields (34 kg·ha^{-1}) of large transplant (five to six true leaves) cabbage (*Brassica oleracea* var. *capitata*) compared with small transplants (four to five true leaves) (5 kg·ha^{-1}) in response to preemergence applications of pendimethalin at 1.7 kg·ha^{-1}. Preemergence herbicide trials conducted in the greenhouse are often criticized for potential leaching and subsequent reduced soil residual activity. Field soil used in our research was excavated from the Quaker Research farm in Lubbock, TX, and contained a natural population of weed seed. Although untreated plant pots were hand-weeded to avoid negative impacts from weed competition, minimal to no weed pressure was observed in any treated pot (data not shown). Therefore, it can be assumed that herbicide leaching was held to a minimum.

Based upon the results of this trial, pendimethalin, prodiamine, dithiopyr, s-metolachlor, oryzalin, isoxaben, and oxadiazon may be used for preemergence weed control in hooker's evening primrose without causing excessive phytotoxicity (>20%) and potential yield loss. Trifluralin + isoxaben treatments exhibited 60% hooker's evening primrose phytotoxicity 28 DAT, which resulted in too low of an initial plant stand to warrant use.

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