Weed Control in Container-grown Herbaceous Perennials

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Abstract. Tolerance of transplanted black-eyed Susan (*Rudbeckia hirta* var. *pulcherrima* Farw.), lanceleaf coreopsis (*Coreopsis lanceolata* L.), shasta daisy (*Chrysanthemum* × *superbum* Bergmans ex. J. Ingram), purple coneflower [*Echinacea purpurea* (L.) Moench.], and blanket flower (*Gaillardia aristata* Pursh) to preemergence herbicides was evaluated in container trials. Herbicides were applied at the maximum use rate and twice the maximum use rate. Dithiopyr, pendimethalin, and prodiamine provided excellent control of spotted spurge (*Euphorbia maculata* L.) and yellow woodsorrel (*Oxalis stricta* L.) with little injury to the five herbaceous perennials. DCPA, oxadiazon, and metolachlor were tolerated by all treated species, but these chemicals provided lower control of one or both weed species. Oryzalin, isoxaben + trifluralin, and napropamide caused unacceptable injury and shoot fresh-weight reductions in some of the perennials at one or both application rates. Chemical names used: dimethyl 2,3,5,6-tetrachloro-1,4-benzenedicarboxylate (DCPA); S,S-dimethyl 2-(difluoromethyl)-4-(2-methylpropyl)-6-trifluoromethyl-3,5-pyridinedicarbothioate (dithiopyr); N-[3-(1-ethyl-1-methylpropyl)-5-isoxazolyl]-2,6-dimethoxybenzamide (isoxaben); 2-chloro-N-(2-ethyl-6-methylphenyl)-N-(2-methoxy-1-methylethyl)acetamide (metolachlor); N,N-diethyl-2-(1-naphthalenenyloxy)propanamide (napropamide); 4-(dipropylamino)-3,5-dinitrobenzenesulfonamide (oryzalin); 3-[2,4-dichloro-5-(1-methylethoxy)phenyl]-5-(1,1-dimethylethyl)-1,3,4-oxadiazol-2-(3H)-one (oxadiazon); N-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzamine (pendimethalin); N,N-di-n-propyl-2,4-dinitro-6-(trifluoromethyl)-m-phenylenediamine (prodiamine); 2,6-dinitro-N,N-dipropyl-4-(trifluoromethyl)benzamine (trifluralin).

The use of wildflowers and other herbaceous perennials in landscapes has increased in recent years (Corley et al., 1989; Gaillitano and Skroch, 1990). To meet this demand, nursery workers are producing these plants in containers. An important concern in container plant production is weed control because weed competition can reduce growth of nursery crops. Shoot dry weight of azalea (*Rhododendron* × 'Fashion') was reduced by as little as one eclipia plant per 3.8- or 15.2-liter container (Berchielli-Robertson et al., 1990).

Weeding by hand is an expensive and time-consuming weed control method in container nurseries—it costs from \$608 to \$1401/ha based on hourly wages from \$3.53 to \$3.97/hour (Gilliam et al., 1990). Using herbicides in container nurseries reduces hand weeding. Annual grasses can be controlled selectively

in nursery crops using preemergence or postemergence herbicides (Derr, 1993a; Senesac and Neal, 1992). Broadleaf weeds are generally harder to control in container nursery production. Because selective postemergence herbicides for broadleaf weeds are not available for most nursery crops, their control depends on preemergence herbicide use. However, information is limited on the tolerance of herbaceous perennials, especially wildflowers, to preemergence herbicides.

Herbaceous perennials that have been evaluated vary in their response to preemergence herbicides (Dickens, 1992; Porter, 1991). Isoxaben plus oryzalin applied posttransplant caused moderate to severe injury to Gloriosa daisy (*Rudbeckia hirta* L.) but did not injure lanceleaf coreopsis (Porter, 1991). In that study, isoxaben injured shasta daisy but not Gloriosa daisy or lanceleaf coreopsis. Nine herbaceous perennials varied in their response to preemergence herbicides registered for turf and ornamental use (Skroch et al., 1990). Oxadiazon and a granular combination of 2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-trifluoromethylbenzene (oxyfluorfen) plus oryzalin injured daylily (*Emerocallus* × 'Aztec Gold'), but other herbicides caused little to no damage (Norcini and Aldrich, 1992).

My objective was to determine the toler-

ance of lanceleaf coreopsis, shasta daisy, black-eyed Susan, purple coneflower, and blanket flower to preemergence herbicides previously reported to cause little or no injury to herbaceous perennials (Dickens, 1992; Skroch et al., 1990). Herbicides were applied at their maximum use rate and at twice their maximum use rate in ornamentals to assess tolerance.

Materials and Methods

General conditions. Plants of lanceleaf coreopsis, shasta daisy, black-eyed Susan, blanket flower, and purple coneflower were grown from seed in a greenhouse using cell packs (6 × 4 × 5 cm) containing a commercial growing medium composed of sphagnum peatmoss, vermiculite, and perlite (Pro-Mix BX, Premier Brands, Yonkers, N.Y.). Plants were transplanted to 4-liter black plastic containers with a 4 pine bark: 1 sand medium (v/v). Each plot was fertilized with a slow-release 17N-2.6P-9.9K (Osmocote 17-6-12; Grace-Sierra, Fogelsville, Pa.) product containing micronutrients at 9 g/pot. Two common weeds in container production, spotted spurge (previously referred to as prostrate spurge) and yellow woodsorrel, were seeded into all containers before herbicide application. These two species are not considered to be as competitive with nursery crops as other broadleaf weeds in container nursery production. Berchielli-Robertson et al. (1990) found that yellow woodsorrel competition had little effect on azalea growth. In that study, one spotted-spurge plant per 3.8-liter container did not reduce azalea growth, although three spotted-spurge plants reduced dry weight by ≈ 15%. Seeds of the two weed species were mixed together with sand, added at ≈ 5 ml/plot, and mixed into the top 2 cm of medium. Plants were maintained outdoors on a gravel-covered site for 3 months after herbicide application and they received ≈ 1.5 cm of water by overhead irrigation daily.

Herbicides were applied broadcast after transplanting, using a CO₂-pressurized backpack sprayer delivering 230 liters·ha⁻¹ for sprayable formulations and a shaker bottle for granular formulations. Herbicides tested, formulation used, and application rates (kg a.i./ha) were as follows: DCPA (75% wettable powder) 13.4 and 27; dithiopyr (1% granular), 2.2 and 4.5; isoxaben + trifluralin (2.5% granular), 1.1 + 4.5 and 2.2 + 9.0; metolachlor (35 g-liter⁻¹ emulsifiable concentrate), 4.5 and 9.0; napropamide (50% wettable powder), 4.5 and 9.0; oryzalin (480 g-liter⁻¹ liquid), 4.5 and 9.0; oxadiazon (2% granular), 4.5 and 9.0; pendimethalin (60% water-dispersible granule), 4.5 and 9.0; and prodiamine (6590 water-dispersible granule), 0.8 and 1.7. The maximum prodiamine rate for turf use was chosen for this study; the dithiopyr rate was based on anticipated maximum rate if the product became registered for ornamental use. Applications for the other herbicides were based on their maximum labeled rate for ornamentals. Plots received overhead irrigation within 4 h of herbicide application.

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The design was a randomized complete block with four replications. Wildflower species were not randomized within plots. There were three pots per species per plot. At 2 and 4 weeks after treatment, plots were visually rated for crop injury using a 0-100 scale (0 = no injury; 100 = plant death). The plot containing the visually highest-quality plants, regardless of treatment, was used as a reference for visual ratings; thus, perennials in the untreated plots could receive a rating other than zero. Spotted spurge and yellow woodsorrel were counted in each plot (18 pots total) 2 months after herbicide application to assess weed control. Only black-eyed Susan and blanket flower produced sufficient flowers during the study for reliable flower counts. Flower counts were taken 3 months after treatment. Crop stand (number of surviving plants per plot) and shoot fresh weight were recorded by species 3 months after herbicide application. The study was conducted twice. Because the results were similar in the two studies, results were combined and analyzed. An analysis of variance was performed on the results with mean separation using the least significance test at $P \leq 0.05$.

Perennials were transplanted and fertilized on 27 May 1992 (spring study), and plants were treated on 28 May 1992. Plant heights at treatment were as follows: lanceleaf coreopsis, 14 cm; shasta daisy, 11 cm; black-eyed Susan, 11 cm; blanket flower, 9 cm; and purple coneflower, 10 cm. At treatment the skies were cloudy; air temperature was 19°C.

In the second study, perennials were transplanted and fertilized on 29 July 1992 (summer study), and plants were treated on 4 Aug. 1992. Plant heights at treatment were as follows: lanceleaf coreopsis, 15 cm; shasta daisy, 6 cm; black-eyed Susan, 8 cm; blanket flower, 8 cm; and purple coneflower, 11 cm. At treatment the skies were partly cloudy; air temperature was 30°C.

Results and Discussion

Degree of injury. Two weeks after herbicide application, the higher rates of oryzalin and napropamide and both rates of isoxaben + trifluralin injured shasta daisy but not the other species (data not shown). Isoxaben + trifluralin applied at the maximum use rate resulted in less injury to shasta daisy than when applied at twice the maximum use rate. The other herbicide treatments caused little to no injury to the five herbaceous perennials at 2 weeks after herbicide application.

At 4 weeks after treatment, both rates of oryzalin and isoxaben + trifluralin had damaged most perennials (Table 1), especially shasta daisy. The higher rate of napropamide also injured shasta daisy. These species could not outgrow the damage observed 2 weeks after herbicide application. The injury observed from isoxaben + trifluralin, napropamide, and oryzalin was primarily stunted growth. Metolachlor caused a foliar burn on all species at the higher rate; injury also was apparent on black-eyed Susan at the lower rate. This injury could be related to the solvent

in the metolachlor formulation. The other treatments caused little to no visible injury to lanceleaf coreopsis, purple coneflower, black-eyed Susan, and blanket flower.

Following isoxaben + trifluralin application, the injury observed in shasta daisy is consistent with the damage reported to shasta daisy from isoxaben (Porter, 1991). Agnew and Hatterman-Valenti (1993) reported that, at 4.5 and 9.0 kg a.i./ha, oryzalin and pendimethalin severely injured *Phlox paniculata* L. and *Physostegia virginiana* L. but did not injure *Aster novi-belgii* L. Pendimethalin caused less injury than oryzalin in this study, although both are dinitroaniline herbicides. However, Neal and Senesac (1991) observed that oryzalin injured six container-grown ornamental grasses, but pendimethalin caused no significant damage. Oxadiazon applied alone did not injure lanceleaf coreopsis

or Shasta daisy according to Skroch et al. (1990), supporting the results observed in this study. Oxadiazon, however, has injured other herbaceous perennials. Oxadiazon has injured liriopie [*Liriope muscari* (Decne) L. H. Bailey] when applied at 4.5 kg a.i./ha, with less injury observed at 2.2 kg a.i./ha (Glaze, 1987). Oxadiazon injured daylily (*Heimerocallis* × 'Aztec Gold'), but plants outgrew the damage according to Norcini and Aldrich (1992). In that study, dithiopyr caused no injury to daylily at rates <2.24 kg a.i./ha.

Plant stand. The higher rate of oryzalin, napropamide, and isoxaben + trifluralin reduced shasta daisy stand (Table 2)—results consistent with the visible injury observed at 4 weeks after treatment (Table 1). Other treatments did not reduce shasta daisy stand. The higher rate of isoxaben + trifluralin was the only treatment to reduce lanceleaf coreopsis

Table 1. Injury severity of five container-grown perennials 4 weeks after herbicide application.

Herbicide	Rate (kg a.i./ha)	Injury severity ^z				
		Shasta daisy	Lanceleaf coreopsis	Purple coneflower	Black-eyed Susan	Blanket flower
Untreated	---	6	1	2	1	2
DCPA	13.4	4	0	1	1	0
	27.0	6	0	2	0	2
Dithiopyr	2.2	4	1	1	3	2
	4.5	8	3	3	5	6
Isoxaben + trifluralin	1.1 + 4.5	29	6	4	14	4
	2.2 + 9.0	53	21	6	25	7
Metolachlor	4.5	3	0	3	1	3
	9.0	11	6	3	8	15
Napropamide	4.5	16	3	3	2	2
	9.0	51	6	7	7	4
Oryzalin	4.5	18	6	5	28	21
	9.0	27	11	8	33	28
Oxadiazon	9.0	2	3	1	3	3
	4.5	4	1	3	4	1
Pendimethalin	4.5	6	2	2	1	1
	9.0	11	4	2	1	2
Prodiamine	0.8	6	3	3	3	1
	1.7	9	1	1	1	2
LSD (0.05)		10	5	3	6	4

^zSeverity rating: 0 = no injury; 100 = plant death.

Table 2. Plant stand for five container-grown perennials 3 months after herbicide application.

Herbicide	Rate (kg a.i./ha)	Plants surviving/plot (no.)				
		Shasta daisy	Lanceleaf coreopsis	Purple coneflower	Black-eyed Susan	Blanket flower
Untreated	---	2.3	3.0	2.5	2.9	3.0
DCPA	13.4	2.4	3.0	3.0	2.5	3.0
	27.0	2.4	3.0	2.9	2.6	3.0
Dithiopyr	2.2	2.6	3.0	2.9	2.9	3.0
	4.5	2.3	3.0	2.6	2.3	3.0
Isoxaben + trifluralin	1.1 + 4.5	1.9	3.0	2.9	2.4	3.0
	2.2 + 9.0	1.1	2.6	3.0	2.3	3.0
Metolachlor	4.5	3.0	3.0	2.6	2.6	3.0
	9.0	2.5	3.0	2.9	2.9	3.0
Napropamide	4.5	2.3	3.0	2.6	2.5	3.0
	9.0	1.1	2.9	2.9	2.5	3.0
Oryzalin	4.5	2.4	3.0	2.1	1.4	2.3
	9.0	1.4	3.0	1.6	1.1	1.6
Oxadiazon	4.5	3.0	3.0	2.6	2.9	3.0
	9.0	2.9	3.0	2.9	2.8	3.0
Pendimethalin	4.5	2.9	3.0	2.8	2.6	3.0
	9.0	2.8	3.0	2.8	2.5	3.0
Prodiamine	0.8	2.6	3.0	2.8	3.0	3.0
	1.7	2.5	3.0	2.9	2.6	2.9
LSD (0.05)		0.7	0.2	0.6	0.6	0.2

Table 3. Shoot fresh weight for five container-grown perennials 3 months after preemergence herbicide application.

Herbicide	Rate (kg a.i./ha)	Shoot fresh wt (g/plant)				
		Shasta daisy	Lanceleaf coreopsis	Purple coneflower	Black-eyed Susan	Blanket flower
Untreated	---	75	161	18	76	116
DCPA	13.4	114	189	32	87	119
	27.0	104	214	29	96	151
Dithiopyr	2.2	96	200	27	80	134
	4.5	70	165	28	61	100
Isoxaben + trifluralin	1.1 + 4.5	46	162	19	60	116
	2.2 + 9.0	37	130	18	57	115
Metolachlor	4.5	115	219	19	89	118
	9.0	95	161	23	74	110
Napropamide	4.5	56	139	8	71	92
	9.0	21	144	8	66	95
Oryzalin	4.5	31	157	5	37	64
	9.0	22	151	3	37	38
Oxadiazon	4.5	104	185	28	75	108
	9.0	105	153	33	80	109
Pendimethalin	4.5	111	193	25	85	130
	9.0	79	163	20	71	112
Prodiamine	0.8	119	172	26	93	127
	1.7	76	180	24	77	130
LSD (0.05)		27	34	8	22	20

stand. Oryzalin was the only treatment to reduce purple cone flower, black-eyed Susan, and blanket flower stands. These species apparently have limited tolerance to oryzalin. In another study, metolachlor applied alone or in combination with oxadiazon did not affect lanceleaf coreopsis, blanket flower, or purple coneflower survival (Derr, 1993b).

Oryzalin reduced flower counts in black-eyed Susan and blanket flower (data not shown). No other treatment affected flowering in these two species. Skroch et al. (1988) did not observe flower injury when DCPA,

metolachlor, or napropamide was applied to 14 spring flowering bulbs, supporting the results observed in this study.

Shoot fresh weights. Shoot weights (Table 3) generally confirmed the visual injury observed at 4 weeks after herbicide application (Table 1). Compared to the untreated control, oryzalin, napropamide, and isoxaben + trifluralin reduced shasta daisy shoot weight. No treatment reduced lanceleaf coreopsis shoot weight. Oryzalin reduced purple coneflower, black-eyed Susan, and blanket flower shoot weights. At the higher rate, napropamide reduced purple cone flower shoot weight. The other herbicide treatments did not reduce purple coneflower, black-eyed Susan, or blanket flower shoot fresh weights.

Weed control. Most treatments controlled spotted spurge and yellow woodsorrel (Table 4), which was expected because the herbicides were evaluated at the maximum use rate and at twice the maximum use rate. However, napropamide provided unacceptably low weed control at both application rates, and metolachlor at 4.5 kg a.i./ha did not adequately control yellow woodsorrel. Oryzalin, isoxaben + trifluralin, and dithiopyr essentially completely controlled both weed species. In another study, acceptable spotted spurge control was observed with oxadiazon, isoxaben, isoxaben + trifluralin, and dithiopyr at lower weed densities, although control was reduced at higher weed populations (Norcini and Aldrich, 1992).

Dithiopyr, pendimethalin, and prodiamine seem to be the most promising candidates for weed control in the perennials tested because all gave excellent spotted spurge and yellow woodsorrel control with little crop injury or

growth reductions. Metolachlor, oxadiazon, and DCPA caused little injury to the perennials tested but were not as effective in controlling one or both of the weed species tested. Unacceptable damage and growth reductions occurred with some of the perennials tested following oryzalin, napropamide, and isoxaben + trifluralin applications. Further research is needed to determine if lower oryzalin and isoxaben + trifluralin application rates could reduce crop damage while maintaining weed control. Weed control with napropamide was unacceptably low, even at twice the maximum use rate.

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Table 4. Weed counts in container-grown wildflowers 2 months after preemergence herbicide application.

Herbicide	Rate (kg a.i./ha)	Weeds/plot (no.)	
		Spotted spurge	Yellow woodsorrel
Untreated	---	28.0	30.6
DCPA	13.4	1.9	1.1
	27.0	0.3	0.3
Dithiopyr	2.2	0.0	0.0
	4.5	0.0	0.0
Isoxaben + trifluralin	1.1 + 4.5	0.0	0.0
	2.2 + 9.0	0.0	0.0
Metolachlor	4.5	1.4	9.1
	9.0	0.0	3.0
Napropamide	4.5	13.0	20.9
	9.0	7.1	10.8
Oryzalin	4.5	0.0	0.0
	9.0	0.1	0.0
Oxadiazon	4.5	2.6	0.0
	9.0	0.4	0.0
Pendimethalin	4.5	0.1	0.0
	9.0	0.0	0.0
Prodiamine	0.8	0.4	0.0
	1.7	0.0	0.0
LSD (0.05)		2.6	5.4