Research Updates

Weed Control and Phytotoxicity of Preemergence Herbicides Applied to Container-grown Herbaceous Plants

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ADDITIONAL INDEX WORDS. herbaceous perennials, napropamide, metolachlor, oxyfluorfen+oryzalin, trifluralin, oxadiazon

SUMMARY. Five preemergence herbicides were applied to seven herbaceous perennials to evaluate weed control efficacy and phytotoxicity. Different species were used each year. The species used during 1992 were coneflower (*Rudbeckia fulgida* Ait. 'Goldstrum'), common foxglove (*Digitalis purpurea* L. 'Excelsior'), Shasta daisy (*Leucanthemum* ×*superbum* Bergmans 'Alaska'), Stokes's aster (*Stokesia laevis* Greene 'Blue Danube'), and avens (*Geum Quellyon* Sweet 'Mrs. Bradshaw'). The species used in 1993 were woolly yarrow (*Achillea tomentosa* L.) and woolly thyme (*Thymus pseudolanuginosus* Ronn.). The herbicides and rates were napropamide (Devrinol 10G) at 4 and 8 lb a.i./acre; metolachlor (Pennant 5G) at 4 and 8 lb a.i./acre; oxyfluorfen+oryzalin (Rout 3G) at 3 and 12 lb a.i./acre; trifluralin (Treflan 5G) at 4 and 8 lb a.i./acre; and oxadiazon (Ronstar 2G) at 4 and 8 lb a.i./acre. Plants were grown in no. 1 containers and weed seeds were sown onto the substrate surface. Two control treatments, no herbicides but with weeds (weedy control), and no weeds or herbicides (weed-free control) also were evaluated. Weed control was effective and similar for all herbicides tested. Napropamide at 8 lb a.i./acre caused stunting in foxglove (20% to 45% less growth compared to weed-free control). Oxyfluorfen + oryzlain at 12 lb a.i./acre caused severe phytotoxicity (≈80% to 95% of plant injured) and stunted the growth (70% to 80% less growth, sometimes plant death) of woolly yarrow. Woolly thyme was stunted by all herbicides when applied at the recommended rates (42% to 97% less growth compared to control) except for oxadiazon and oxyfluorfen + oryzlain. Woolly thyme appeared to be more susceptible to phytotoxicity due to its less-vigorous growth habit and shallow, adventitious roots that were in contact with the herbicide.

Department of Horticulture and Landscape Architecture, Colorado State University, Fort Collins, CO 80523. Funding was provided by Colorado Experiment Station (Project 713) and Western Region Pesticide Impact Assessment and IR-4 Minor Use Programs. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

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An increase in the popularity of herbaceous perennials has stimulated production and increased sales (Sallee, 1991a, 1991b). Weed control is one of the main concerns of many growers. Since weeds compete with crops for moisture, nutrients, and light, decreased crop growth is often the result of uncontrolled weeds. Reported growth losses of herbaceous perennials range from 47% to 75%, depending on the crop and/or weed species and weed densities (Fretz, 1972a; Gibson, 1985). Removing the weeds by hand is very labor intensive and adds to production costs. It takes 575 to 675 h of manual labor to hand weed 1 acre (0.4 ha) of no. 1 containers (Carpenter, 1973; Fretz, 1972a, 1972b; Padgett and Frazier, 1962).

Herbicide applications are an effective and economical way to control weeds and produce saleable plants. Hand labor for weed control can be reduced by 80% when herbicides are used (Bingham, 1968). Although herbicides may be an effective and economical way to control weeds, some herbicides have caused phytotoxicity to some herbaceous species (Akers et al., 1984; Derr, 1993). Phytotoxicity was observed with oryzalin on *Ajuga reptans purpurea* (Schuett and Klett, 1988), *Phlox paniculata*, *Gypsophila pacifica*, and *Stachys byzantina* (Staats and Klett, 1993). Isoxaben resulted in stunting in *Stachys byzantina* (Staats and Klett, 1993). The objective of this study was to 1) evaluate herbicide control of common weeds in container grown herbaceous perennials and 2) determine crop tolerance.

Materials and methods

In 1992 five herbaceous perennials were evaluated and in 1993 the experiment was repeated with two different perennial species. Perennials were chosen based on requests to the Interregional Research Project No. 4 (IR-4) by the nursery trade and other researchers. IR-4 is responsible for pesticide research on minor crops (grown in relatively small amounts) that have few registered herbicides. Weed species were selected based on a survey of weeds found in regional nurseries.

1992 SEASON. Four preemergence herbicides—napropamide [*N*,*N*-diethyl-2-(1-naphthalenyloxy) propanamide] as Devrinol 10G (Zeneca Ag Products in Wilmington, Del.); metolachlor [2-chloro-*N*-(2 ethyl-6-methylphenyl)-*N*-(2 methoxy-1-methyethyl) acetamide] as Pennant 5G (Novartis in Greensboro, N.C.); oxyfluorfen + oryzalin (2 chloro-1-(3-ethoxy-4-nitro-

Table 1. Herbicides used in 1992 and change in height, change in width, and final dry weights of foxglove when used with four different herbicides.

Treatment	Rate	Herbicide (lb a.i./acre)	Per plant Ht (cm)	Width (cm)	Dry wt (g)
Weed-free control	---	---	10.1	28.7	118.5
Weedy control	---	---	7.0	26.7	108.0
Napropamide (Devrinol 10G)	1×	4	8.7	22.5**	108.6
	2×	8	5.3**	19.7**	95.9**
Metolachlor (Pennant 5G)	1×	4	10.1	26.7	111.9
	2×	8	9.5	24.5	106.7
Oxyfluorfen + Oryzalin (Rout 3G)	1×	3	8.5	27.1	110.5
	4×	12	9.6	25.1	103.5
Trifluralin (Treflan 5G)	1×	4	10.1	23.9	121.7
	2×	8	7.3	24.1	120.8

**Less than the weed-free control treatment at $p = 0.01$.

phenoxy)-4 (trifluoromethyl) benzene + 4-(dipropylamino)-3,5-dinitrobenzene sulfonamide) as Rout 3G (Scotts Co., Marysville, Ohio); and trifluralin (2,6-dinitro-*N*,*N*-dipropyl-4-(trifluoromethyl) benzenamine) as Treflan 5G (Dow-Elanco in Indianapolis, Ind.)—were evaluated using five plant species—coneflower (*Rudbeckia fulgida* Ait. 'Goldstrum'), common foxglove (*Digitalis purpurea* L. 'Excelsior'), Shasta daisy (*Leucanthemum* ×*superbum* Bergmans 'Alaska'), Stokes's aster (*Stokesia laevis* Greene 'Blue Danube'), and avens (*Geum Quellyon* Sweet 'Mrs. Bradshaw'). Herbaceous perennials were obtained from commercial growers in 2.25-inch (5.7-cm) containers and transplanted into no. 1 containers [6.1 inch (15.5 cm) diameter across the top, 5.3 inches (13.5 cm) across the bottom and 6.9 inches (17.5 cm) high] on 20 Apr. 1992. Plants were allowed to establish until the treatments were applied. The potting media consisted of sphagnum peat, washed sand (ASTM C-33 'fine aggregate'), and a Nunn clay loam soil (2:1:1, by volume). The rooting medium for all treatments was pasteurized to kill any possible existing weed seeds. Each plant was fertilized with 0.53 oz (15 g) of Osmocote (21N–4P–7K) on 5 May 1992.

For each herbicide, four different treatments were compared: 1×, 2×, weed-free, and weedy control. The 1×, 2×, and weedy control treatments all had weed seeds sown by hand on the medium's surface. The weedy control treatment received no herbicide. The 1× and 2× treatments received one and two times the labeled rate (Table 1). The 2× rate was used to determine if weed control could be increased without increasing the risk of phytotoxicity. Oxyfluorfen + oryzalin was applied at a 4× instead of the 2× rate as a special request by the manufacturer. The weed-free control plants had no weed seeds or herbicides applied. The weed-free control was used to determine ideal growth without potential complications from weeds or phytotoxicity.

A mix of weed seeds were sown by hand onto the medium's surface on 2 June 1992 before herbicide application to ensure a weed population. Weeds were sown at the following rates: yellow foxtail (*Setaria glauca* (L.) Beauv.) at 10 seeds/pot, barnyard-grass (*Echinochloa crus-galli* (L.) Beauv.) at 13 seeds/pot, annual bluegrass (*Poa annua* L.) at 18 seeds/pot, shepherdspurse (*Capsella bursa-pastoris* (L.) Medicus) at 25 seeds/pot, common groundsel (*Senecio vulgaris* L.) at 13 seeds/pot, and redroot pigweed (*Amaranthus retroflexus* L.) at 20 seeds/pot. On 4 June 1992, granular herbicides were applied by hand to the medium's surface and irrigated with 0.75 inch (2 cm) of water.

Weed counts and phytotoxicity ratings (1 = no damage, 10 = plant death) were taken every 4 weeks. Height and width measurements of crop species were taken at the beginning and end of the experiment (14 Sept. 1992). Dry weights of the above-ground biomass were taken by cutting the plants at the soil surface 14 weeks after herbicide application and then drying at 158 °F (70 °C) for 48 h. Experiments were designed as randomized complete blocks with five replications. Plants were grown outdoors in full sun on lath frames 3 inches (7.6 cm) above asphalt paving. Orthogonal contrasts at $p = 0.05$ were used to analyze data. Herbicide treatments were compared to the weed-free control treatment.

1993 SEASON. The same herbicides used in 1992 were evaluated in 1993 with the addition of oxadiazon (3-[2,4-dichloro-5-(1-methylethoxy) phenyl]-5-(1,1-dimethylethyl)-1,3,4-oxadiazol-2-(3*H*)-one) as Ronstar 2G (Rhone-Poulenc Inc., Research Triangle Park, N.C.). The two rates used for oxadiazon were 1× = 4 lb a.i./acre and 2× = 8 lb a.i./acre. In 1993 two different crop species were evaluated: woolly yarrow (*Achillea tomentosa* L.) and woolly thyme (*Thymus pseudolanuginosus* Ronn.). Growing medium, pot size, plant size, weed species, treatments, and application methods were the same as used in the 1992 study. All perennials were planted into no. 1 pots by 20 Mar. 1993 and fertilized with 0.53 oz (15 g) of Osmocote (21N–4P–7K) on 14 June 1993. Weed seeds were sown on 10 June 1993 and herbicides were applied on 11 June 1993. The experiment was concluded 13 weeks after herbicide application and plants were cut to the ground to obtain dry weights on 17 Sept. 1993.

Weed counts and phytotoxicity ratings (1 = no damage, 10 = plant death) were taken every 4 weeks. Height and width measurements of crop species were taken at the beginning and end of the experiment. Dry weights of the above-ground biomass were taken by cutting the plants at the soil surface and then drying at 158 °F (70 °C) for 48 h. Experiments were designed as randomized complete blocks with five replications. Plants were grown outdoors in full sun on lath frames 3 inches (7.6 cm) above asphalt paving. Orthogonal contrasts at $p = 0.05$ were used to analyze data. Herbicide treatments were compared to the weed-free control treatment.

Results and discussion

Shasta daisy, avens, and Stoke's aster did not have any phytotoxicity or stunting (data not shown). All the herbicides compared in this study appear to be viable options for effective weed control with these species.

Napropamide was the only herbicide to injure foxglove (Table 1). Napropamide at 4 lb a.i./acre caused stunting (measured by change in plant width) (Table 1). Plants were slightly smaller but still looked healthy. Napropamide at 8 lb a.i./acre reduced growth, width, and dry weight of foxglove compared to untreated plants (Table 1).

No herbicide injured coneflower compared to the weed-free control. Visual symptoms of foliar phytotoxicity were not apparent at any time during the season. All treatments were similar in size to the control (data not shown). However, when the 1× treatments were contrasted with the 2× treatments, the 2× rates were smaller (12% less in height, 15% less in dry weight) ($p = <0.01$). This indicates growers could experience a slight stunting of coneflower when using higher rates of herbicides.

Woolly yarrow was not adversely affected by the use of any herbicides except oxyfluorfen + oryzalin at 12 lb a.i./acre (Table 2). Although plants treated with oxyfluorfen + oryzalin at 3 lb a.i./acre rate looked healthy, oxyfluorfen + oryzalin at 12 lb a.i./acre rate resulted in severe phytotoxicity and often death of the plant.

Woolly thyme was affected by all herbicides except oxadiazon at 4 and 8 lb a.i./acre) and oxyfluorfen + oryzalin at 3 lb a.i./acre) (Table 2). Metolachlor at 4 and 8 lb a.i./acre and napropamide at 4 lb a.i./acre caused foliar phytotoxicity (chlorosis and some necrosis) on at least 50% of the plants. Metolachlor and napropamide also reduced growth (dry weights and width) compared to the weed-free control treatment (Table 2). Trifluralin at 4 and 8 lb a.i./acre reduced plant growth (width and dry weight) when contrasted to the weed-free control treatment and had visual symptoms of phytotoxicity at 8 lb a.i./acre (Table 2). Oxyfluorfen+oryzalin at 12 lb a.i./acre reduced woolly thyme dry weights but caused no phytotoxicity.

Phytotoxicity was more common with woolly thyme than with any other species studied. The increased injury may be a result of the less-vigorous growth habit of woolly thyme and a large percentage of shallow, adventitious roots coming in contact with the soil surface and the herbicide. Woolly thyme appears to be more susceptible to injury than woolly yarrow, despite similar growing habits, because it is a smaller, less-vigorous plant with foliage more concentrated next to the surface where the herbicide was applied.

All preemergence herbicides in this study provided effective weed control ranging between 76% and 98% compared to the weedy control (Table 3). Overall weed control was the same for all herbicides except for napropamide at 4 lb a.i./acre and trifluralin at 4 and 8 lb a.i./acre. Napropamide at 4 lb a.i./acre allowed more weeds than metolachlor at 8 lb a.i./acre or oxyfluorfen + oryzalin at 12 lb a.i./acre ($p < 0.05$). Trifluralin at 4 and 8 lb a.i./acre allowed more weeds than oxyfluorfen+oryzalin at 12 lb a.i./acre ($p < 0.05$). Overall, the 2× rates did not provide greater weed control than the standard recommended rates ($p < 0.05$). Of all the herbicides tested (at recommended rates), oxyfluorfen+oryzalin and oxadiazon provided the best weed control with no phytotoxicity problems.

Analysis of specific weed species (Table 3) found no differences ($p < 0.05$) in the control of common groundsel among the herbicides except for trifluralin at 8 lb a.i./acre, and that probably was an application problem since the 4 lb a.i./acre treatment resulted in good control of common groundsel. Shepherdspurse did not establish in large enough quantities to indicate differences even with the weedy control treatment Redroot pigweed, yellow foxtail, and barnyardgrass were controlled similarly by all herbicides ($p < 0.05$). Control of annual bluegrass for oxyfluorfen + oryzalin at 3 lb a.i./acre and trifluralin at 4 lb a.i./acre was less than with the other herbicides (Table 3).

Weeds were more numerous in the 1993 study as a result of the growth habits of the plants that were used. In 1993 woolly yarrow and woolly thyme,

Table 2. Change in width, final dry weight of top growth and phytotoxicity ratings[z] of woolly yarrow and woolly thyme when used with five different herbicides in 1993.

Herbicide treatment	Change in width (cm)		Dry wt (g)		Phytotoxicity rating	
	Yarrow	Thyme	Yarrow	Thyme	Yarrow	Thyme
Weed-free control	11.5	34.06	13.1	27.69	1.0	1.0
Weedy control	3.0*	–0.50**	0.5*	1.45**	1.0	1.0
Napropamide, 4 lb a.i./acre	12.5	13.24**	10.1	8.70**	1.0	4.6*
Napropamide, 8 lb a.i./acre	19.4	25.20	18.7	16.30	1.0	2.0
Metolachlor, 4 lb a.i./acre	17.5	3.00**	18.9	2.56**	1.0	4.8
Metolachlor, 8 lb a.i./acre	19.3	0.90**	21.1	2.77**	1.0	4.4*
Oxyfluorfen+ oryzalin, 3 lb a.i./acre	15.9	30.20	18.7	22.64	1.0	1.0
Oxyfluorfen + oryzalin, 12 lb a.i./acre	3.3*	23.78	2.7*	15.99**	8.2**	1.0
Oxadiazon, 4 lb a.i./acre	16.4	27.60	18.7	20.26	1.0	1.0
Oxadiazon, 8 lb a.i./acre	19.1	27.40	20.6	22.07	1.0	1.0
Trifluralin, 4 lb a.i./acre	11.5	15.08**	9.5	9.61**	1.0	1.8
Trifluralin, 8 lb a.i./acre	14.3	15.60**	15.1	11.95**	1.0	3.2*

[z]No phytotoxicity = 1, dead =10.

*,**Significantly different than the control treatment at $p = 0.05$ or 0.01, respectively.

Table 3. Weeds per container averaged over the 1992 and 1993 growing seasons. Oxadiazon was applied in 1993 only.

Herbicide treatment	Mean no. weeds/ container	Weeds controlled (%)	Individual weed species not controlled/no. 1 container: Common groundsel	Shepherds-purse	Pig-weed	Fox-tail	Barnyard-grass	Annual bluegrass
Weed-free control	0.0	100			No weeds			
Weedy control	3.17^{**}	0	0.54^{*}	0.17^{NS}	0.54^{**}	0.83^{**}	0.89^{**}	0.20^{*}
Napropamide, 4 lb ai/acre	0.77^{z}	76	0.14	0.23	0.14	0.14	0.06	0.06
Napropamide, 8 lb ai/acre	0.57	82	0.20	0.20	0.03	0.11	0.03	0.00
Metolachlor, 4 lb ai/acre	0.37	88	0.23	0.03	0.06	0.03	0.00	0.03
Metolachlor, 8 lb ai/acre	0.11	97	0.03	0.03	0.00	0.03	0.00	0.03
Oxyfluorfen + oryzalin, 3 lb ai/acre	0.48	84	0.17	0.06	0.06	0.03	0.03	0.14^{x}
Oxyfluorfen + oryzalin, 12 lb ai/acre	0.06	98	0.00	0.03	0.00	0.00	0.00	0.03
Oxadiazon, 4 lb ai/acre	0.30	91	0.20	0.00	0.00	0.00	0.10	0.00
Oxadiazon, 8 lb ai/acre	0.30	91	0.30	0.00	0.00	0.00	0.00	0.00
Trifluralin, 4 lb ai/acre	0.66^{y}	79	0.03	0.23	0.09	0.09	0.06	0.17^{x}
Trifluralin, 8 lb ai/acre	0.66^{y}	79	0.34	0.29	0.00	0.03	0.00	0.00

[z]Greater than metolachlor at 8 lb a.i./acre and oxyfluorfen + oryzalin at 12 lb a.i./acre ($p = 0.05$).
[y]Greater than oxyfluorfen+oryzalin at 12 lb a.i./acre ($p = 0.05$).
[x]Greater than all other herbicide treatments ($p = 0.05$).
*,**Significantly greater than the herbicide treatments at $p = 0.05$ or 0.01, respectively. Herbicide treatments without superscripts are similar within columns.

which have low creeping growth habits, may have allowed more light to reach the soil surface resulting in more weed seed germination. Overall, the weed control among herbicides was similar for both years.

The presence of weeds did not decrease plant size for coneflower, avens, Shasta daisy, Stokes aster, or foxglove, but they made them unmarketable from a visual perspective. Weeds reduced width and dry weights of woolly yarrow and woolly thyme (Table 2). The difference may be due to the fact that the woolly yarrow and wooly thyme groundcovers are low, creeping plants and are not able to compete as well against the weeds as were the taller plants used in the 1992 study.

The use of preemergence herbicides may be reduced depending on the plant species. In this study most plant species growth habits allowed numerous weeds to develop. However, weed seeds sown in the container with foxglove were shaded by vigorously growing plants with large leaves and the weeds never grew past the seedling stage. Growers could save on labor and material expenses by taking advantage of similar plant growth habits and cultural conditions.

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