HRI's Mission:

To direct, fund, promote and communicate horticultural research, which increases the quality and value of ornamental plants, improves the productivity and profitability of the nursery and landscape industry, and protects and enhances the environment.

Weed Control and Phytotoxicity Following Preemergence Herbicide Applications to Container-grown Herbaceous Plants[1]

James E. Klett, David Staats, Teri Howlett and Matthew Rogoyski[2]
Department of Horticulture and Landscape Architecture
Colorado State University, Fort Collins, CO 80523

Abstract

Effectiveness of five preemergence herbicides was determined for four container-grown ornamental crops. Herbicides tested were Barricade (prodiamine); BroadStar (flumioxazin); Gallery (isoxaben); Scotts Ornamental Weedgrass Control (Scotts OWC) (pendimethalin); and Treflan (trifluralin). Four herbaceous plant species were utilized in this trial, namely, Guizhou sage (*Artemisia lactiflora* Wall. (Guizhou group)); hopflower oregano (*Origanum libanoticum* Boiss.); Daghestan sage (*Salvia daghestanica* Sosn.); and skullcap (*Scutellaria resinosa* Torr.). The seven weed species evaluated in this trial were annual bluegrass (*Poa annua* L.); barnyardgrass (*Echinochloa crus-galli* L.); yellow foxtail grass (*Setaria glauca L.*); purslane (*Portulaca oleracea L.*); common groundsel (*Senecio vulgaris* L.); redroot pigweed (*Amaranthus retroflexus* L.); and annual sowthistle (*Sonchus oleraceus L.*). Two controls, one with weeds and one without were also evaluated. The experiment was conducted in two locations: Fort Collins and Grand Junction, Colorado. Weed control levels varied across a range of herbicide treatments and ornamental species. Where differences among herbicides were observed, BroadStar and Treflan tended to be more effective than the other herbicides, while Gallery, Scotts OWC and Barricade, were less effective. Plants treated with Gallery often resulted in decreased dry weights; however, no visual phytotoxicity symptoms were observed with any herbicide treatments. Daghestan sage and skullcap were the crop species most adversely effected.

Index words: herbaceous perennials, preemergence herbicides, weed control, phytotoxicity.

Species used in this study: Guizhou sage (*Artemisia lactiflora* Wall. (Guizhou group)); hopflower oregano (*Origanum libanoticum* Boiss.); Daghestan sage (*Salvia daghestanica* Sosn.); skullcap (*Scutellaria resinosa* Torr.); annual bluegrass (*Poa annua* L.); barnyardgrass (*Echinochloa crus-galli* L.); yellow foxtail grass (*Setaria glauca* L.); purslane (*Portulaca oleracea* L.); common groundsel (*Senecio vulgaris* L.); redroot pigweed (*Amaranthus retroflexus* L.); annual sowthistle (*Sonchus oleraceus* L.).

Herbicides used in this study: Barricade (prodiamine), 2,4-dinitro-N3,N3-dipropyl-6-(trifluoromethyl)-1,3-benzenediamine; Treflan (trifluralin), 2,6-dinitro-N,N-dipropyl-4-(trifluoromethyl)benzenamine; BroadStar (flumioxazin), 2-[7-fluoro-3,4-dihydro-3-oxo-4-(2-propynyl)-2H-1,4-benzoxazin-6-yl]-4,5,6,7-tetrahydro-1H-isoindole-1,3(2H)-dione; Gallery (isoxaben), N-[3-(1-ethyl-1-methylpropyl)-5-isoxazolyl]-2,6-dimethoxybenzamide; and Scotts OWC (pendimethalin), N-(l-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzeneamine.

Significance to the Nursery Industry

Treflan and BroadStar are effective and minimally injurious for use on Guizhou sage and hopflower oregano. Additionally, Barricade is effective on hopflower oregano. Effective weed control is achieved with Treflan and BroadStar for Daghestan sage, but plant injury was exhibited.

Specifically, herbicides Treflan and BroadStar at label rate (1×) provided Guizhou sage planted in containers with weed control of 90 and 92%, respectively. Guizhou sage treated with Gallery and Scotts OWC resulted in the greatest dry weight reductions. The best weed control at label rate for hopflower oregano was from Treflan, BroadStar, and Barricade with 93, 91, and 85% weed control, respectively. Gallery treated hopflower oregano resulted in an over 50% dry mass reduction. Weed control was 96 and 83% with 1× BroadStar and Treflan with Daghestan sage. All herbicides caused dry weight reductions with Daghestan sage; but less reduction was observed with BroadStar and Treflan. The best weed control with skullcap at 1× rate was with Scotts OWC which controlled 78% of weeds. All herbicides dramatically reduced skullcap dry weight except BroadStar. The variability between species and specific herbicides, as indicated by this study and other research, suggests as new plant species and new preemergence herbicide formulations are introduced, further evaluation will be needed.

[1]Received for publication July 12, 2006; in revised form August 27, 2007. Funding was provided by Colorado Experiment Station (Projects 713 and 157) and Western Region Pesticide Impact Assessment and IR-4 Minor Use Programs.

[2]Professor, research associate, graduate student, and assistant professor, respectively. Department of Horticulture and Landscape Architecture, Colorado State University.

Introduction

American landscapes are becoming more diverse utilizing year round color and texture that ornamentals provide. Since the market increase of perennials (9) in the late 1980s, landscape professionals have been designing with an ever increasing spectrum of color, size, and texture. Homeowners, in addition to landscape professionals, are strongly attracted to the array of landscape possibilities that perennials provide. Commercial production of landscape perennials is increasing to provide a level of plant diversity that meets the demand of the consumer and professional.

Weed control is especially important to the profitable production of container nursery crops. Aesthetics often determine whether the plant is marketable or not. Poor crop growth will also diminish the aesthetics and salability of landscape plants (11, 27). Weed competition for limited container space results in reduced growth of container nursery crops (4, 12).

One method to control weeds is hand weeding, however as a result of high labor costs, hand weeding is not cost effective. Approximately $500 to $4000/acre is spent by nursery growers to remove weeds by hand (16).

An alternative to hand weed control is use of preemergence herbicides. Neal (20) states that 'preemergence herbicides remain the safest and most cost efficient means of controlling annual weeds in container-grown nursery stock.' Granular or liquid formulated herbicides can be applied overhead by a calibrated sprayer or granular dispenser. The herbicides are then watered in (27) to create a chemical barrier of herbicide across the upper layer of growing media to disrupt growth of the weed seedlings (6). Container crop species react to herbicides differently (23); therefore the same herbicide cannot be safely applied to all species.

Another approach that is being investigated to control weeds is cultural control. This approach uses sub-irrigation, large-porous container media, mulching, and covering the media to minimize weed growth (6). This method may play an important role for weed control in the future.

Currently, weed control in container production is commonly achieved through a combination of preemergence herbicides and hand weeding (3). This is in part due to the lack of available herbicides labeled for perennial herbaceous crops.

Herbicide labels only list a limited number of herbaceous perennials. As of 2002, there were 315 listed herbicides available for use on soybeans, cotton, other commodity crops, and ornamentals (28). However, the number of herbicides available to the ornamental industry is small (6, 7). The large number of ornamental species that could be labeled is limited by the relatively small amount of herbicide tolerance testing (11, 17). Studies to gather this data are conducted each year through the USDA IR-4 program.

The demand for new species and varieties of perennials (22) and the difficult task of producing healthy, weed free, saleable stock in a cost efficient manner, warrants the continued evaluation of preemergence herbicides for use on herbaceous perennials.

The experiment objective was to determine how four herbaceous species, Guizhou sage, hopflower oregano, Daghestan sage, and skullcap, would each react to preemergence herbicide applications at two locations.

Materials and Methods

Four container grown herbaceous perennials; Guizhou sage, hopflower oregano, Daghestan sage, and skullcap were treated with five preemergence herbicides: Barricade 65WG; Treflan 5G; BroadStar; Gallery; and Scotts OWC. The same study was conducted at two sites (Fort Collins and Grand Junction, CO) in 2002 to provide different environmental conditions and to replicate the experiment. Grand Junction experiences warmer temperatures and a longer growing season than Fort Collins. Methods and materials were the same for both sites except for site conditions and slightly different harvest dates at the end of the study. All plants were received in 5.7 cm (2.3 in) pots and transplanted into #1 (21.6 × 21.6 × 17.8 cm) (8.5 × 8.5 × 7 in) containers on April 29, 2002. Potting medium was a commonly used commercial product (Outdoor Mix) from Organix in Platteville, CO, made from sphagnum peat, composted dry poultry waste, pumice, and bark. The percentage of organic matter was 45.36% and the pH was 6.8. Each plant was fertilized with 15 g (0.03 lb) of Osmocote (19–6–12) shortly after planting on May 3, 2002. Twenty pre-counted seeds each of annual bluegrass, barnyardgrass, yellow foxtail grass, purslane, common groundsel, redroot pigweed, and annual sowthistle were sown onto the medium surface (8, 15) and incorporated approximately 1.3 to 1.9 cm (0.5 to 0.75 in) deep into the medium on June 3, 2002. Herbicide treatments were applied after the weed seeds were applied on June 3, 2002, and herbicides were activated by applying 2 cm (0.8 in) of water (27) by overhead irrigation. Five herbicide treatments were used as well as two control treatments. The two control treatments were a hand weed control consisting of a single plant in a container with no herbicide or weed seeds applied and a weedy control consisting of a single plant in a container with no herbicide but sown weed seeds. The hand weed control treatment was generally weed-free since a pasteurized commercial medium was utilized but the occasional weed that would blow in was removed by hand as needed. The five herbicide treatments consisted of two rates: 1× (the labeled rate) and 2× (twice the labeled rate) (Tables 1, 2, 3, 4). Granular herbicides were weighed and separately applied (5) to the soil media surface. Liquid herbicides were applied in a spray chamber (Model #SB8-095, De Vries Manufacturing, Hollandale, MN 56045) with a 43 psi calibrated boom and 8002E nozzle, with a spray rate of 17.44 gal/A.

Plant containers in Fort Collins were placed on wire mesh platforms raised 10.2 cm (4 in) above a weed fabric surface and plant containers in Grand Junction were placed on a surface of crushed gravel.

The plant species were watered as needed during the growing season by drip irrigation. The timing was adjusted for warmer days and the drip system ran until the container medium was at field capacity with some water running out the bottom of the container. Two weed counts were taken, the first on July 5, 2002, and the second count on August 29, 2002. Plants were first observed for phytotoxicity with a 0–10 scale (6, 21, 26) where 0 = no damage and 10 = plant death on July 8, 2002 (Grand Junction), and July 15, 2002 (Fort Collins). A second observation for phytotoxicity was taken on September 10, 2002 (Grand Junction), and September 12, 2002 (Fort Collins). Height and width measurements (24) were recorded in cm before the treatments were applied (May 24, 2002) and at the end of the season (September 6, 2002). Dry weights of the above ground biomass from the four herbaceous species were measured by clipping each ornamental plant at the soil level, placing it in a paper bag, and drying at 70C (158F) for 48 hours. Plants were harvested on September 13, 2002 (Fort Collins), and October 9, 2002 (Grand Junction). Experiments were in a randomized complete block design. Data was subjected to analysis of variance and mean separation by Student-Newman-Keuls test.

Results and Discussion

All five herbicide treatments had some level of effectiveness in controlling weeds for the four container-grown crops at both Fort Collins and Grand Junction locations. The weed control ranged from 46 to 100% control. Some treatments, despite reducing the number of weed seedlings, did not provide commercially adequate weed control.

The experiments included two control treatments, hand weed control and weedy control. These non-weed seeded and weed seeded controls resulted in uniform weed pressure across the weedy treatment containers (Tables 1, 2, 3, 4). Two weed counts were conducted, with only noteworthy results being shown (Tables 1, 2, 3, 4). The control containers in which weed seeds were not introduced remained largely weed free during the experiment. Typically in the weedy control,

Table 1. Effect of selected preemergent herbicides on dry weight and weed counts in container grown Guizhou sage 32 and 87 days following treatment at two locations.

Herbicide	Rate		Dry weight g/pot		Weed count[z] (no./pot)											
					Total weed count[y]		Annual bluegrass[y]		Barnyard grass[y]		Purslane[y]		Groundsel[y]		Sowthistle[x]	
	kg/ha	lb/A	FC[w]	GJ[v]	FC	GJ	FC	GJ	FC	GJ	FC	GJ	FC	GJ	FC	GJ
Hand weed control	—	—	30.5a[z]	39.2ab	0.0c	0.6d	0.0b	0.0c	0.0a	0.0c	0.0c	0.0a	0.0b	0.0a	0.0b	0.0b
Weedy control	—	—	12.0bc	27.5ab	18.4a	16.0a	1.4a	4.6a	1.0a	3.2a	3.2a	1.0a	0.4ab	0.4a	0.6b	1.0a
Barricade 65WG	0.73	0.65	20.2abc	36.1ab	4.4bc	2.8bcd	0.0b	0.2c	0.4a	0.0c	1.6bc	0.4a	0.0b	0.8a	2.0a	1.0a
	1.46	1.3	23.6ab	32.5ab	1.6c	1.4cd	0.0b	0.6c	0.2a	0.0c	0.0c	0.2a	0.6ab	0.2a	0.6b	0.4ab
Treflan 5G	4.5	4	26.4ab	49.0a	1.8c	0.4d	0.2b	0.0c	0.0a	0.0c	0.4c	0.0a	0.0b	0.0a	0.8b	0.2ab
	9.0	8	26.2ab	42.7ab	0.6c	0.4d	0.0b	0.0c	0.0a	0.0c	0.2c	0.0a	0.4ab	0.4a	0.4b	0.0b
BroadStar	0.28	0.25	27.6ab	39.6ab	1.4c	0.2d	0.0b	0.0c	0.0a	0.0c	0.0c	0.0a	0.0b	0.0a	0.0b	0.0b
	0.56	0.5	27.6ab	34.4ab	0.0c	0.6d	0.0b	0.0c	0.0a	0.0c	0.0c	0.0a	0.0b	0.0a	0.0b	0.0b
Gallery	1.1	1	6.8c	25.1b	4.0bc	5.8b	0.8ab	3.8a	1.2a	1.8b	0.0c	0.0a	0.2b	0.0a	0.0b	0.0b
	2.2	2	12.8bc	7.2c	4.0bc	4.8bc	0.6ab	2.2b	0.2a	1.8b	0.0c	0.0a	0.0b	0.4a	0.0b	0.0b
Scotts OWC	2.2	2	15.0abc	22.6b	8.0b	3.0bcd	0.2b	0.6c	0.6a	0.8bc	2.4ab	0.2a	1.2a	0.2a	2.0a	0.4ab
	4.5	4	23.9ab	42.0ab	2.0c	1.2cd	0.0b	0.0c	0.2a	0.2c	0.6c	0.0a	0.0b	0.4a	0.4b	0.2ab

[z]Means with the same letter are not significantly different (SNK, $P \leq 0.05$). Only noteworthy weed efficacy results are shown.

[y]Data acquired July 5, 2002.

[x]Data acquired August 29, 2002.

[w]Fort Collins, CO.

[v]Grand Junction, CO.

there were usually more than 15 weed plants per container (Tables 1, 3, 4). Containers of hopflower oregano had fewer weeds (Table 2), and this could be due to the vigorous spreading growth habit of hopflower oregano.

When specific crop data was examined for effectiveness of herbicides in controlling weeds, the results varied among herbicides and locations. General weed control efficacy with Guizhou sage plants showed weed control efficacies of 90 and 92% for Treflan and BroadStar. Barricade, Gallery, and Scotts OWC were 76, 63, and 56%, respectively (Table 1). Scotts OWC at the Fort Collins location and Gallery at Grand Junction at the 1× rate provided only fair (56–63%) weed control. A doubled rate (2×) improved Barricade's and Scotts' efficacies. This is consistent with Nagy's suggestion for use of Treflan at a 5 kg/ha rate for new plantings of *Artemisia* (19). Guizhou sage treated with 1× Scotts OWC in Fort Collins provided significantly less effective weed control against purslane, groundsel, and sowthistle (Table 1). Barricade at the 1× rate was significantly less effective at both Fort Collins and Grand Junction in controlling sowthistle. Gallery at both rates at the Grand Junction site was significantly less effective in controlling grass weeds.

General weed control efficacy from all herbicides tested for hopflower oregano ranged between 46 to 100% (Table 2).

Table 2. Effect of selected preemergent herbicides on dry weight and weed counts in container grown hopflower oregano 32 and 87 days following treatment at two locations.

Herbicide	Rate		Dry weight g/pot		Weed count[z] (no./pot)											
					Total weed count[y]		Groundsel[y]		Sowthistle[x]		Annual bluegrass[y]		Barnyard grass[y]		Foxtail grass[x]	
	kg/ha	lb/A	FC[w]	GJ[v]	FC	GJ	FC	GJ	FC	GJ	FC	GJ	FC	GJ	FC	GJ
Hand weed control	—	—	37.0a[z]	39.7a	0.0c	0.6c	0.0a	0.0b	0.0a	0.4ab	0.0b*	0.0b	0.0b	0.0c	0.0c	0.0b
Weedy control	—	—	21.0abc	23.5b	9.8a	8.6a	0.0a	0.0b	1.2a	0.4ab	1.0b	0.2b	3.4a	2.2a	2.2a	1.0a
Barricade 65WG	0.73	0.65	32.1ab	33.7a	1.4bc	1.2c	0.0a	0.4ab	0.6a	0.6ab	0.0b	0.0b	0.2b	0.0c	0.0c	0.0b
	1.46	1.3	32.1ab	35.2a	0.4c	1.8c	0.0a	0.6a	0.0a	1.2a	0.0b	0.0b	0.4b	0.0c	0.0c	0.0b
Treflan 5G	4.5	4	28.7ab	41.1a	0.4c	0.6c	0.0a	0.2b	0.0a	0.0b	0.0b	0.0b	0.2b	0.0c	0.0c	0.0b
	9.0	8	33.0ab	39.3a	0.8bc	0.4c	0.0a	0.0b	0.4a	0.4ab	0.2b	0.0b	0.0b	0.0c	0.0c	0.0b
BroadStar	0.28	0.25	26.6ab	42.4a	0.8bc	0.0c	0.0a	0.0b	0.0a	0.0b	0.0b	0.0b	0.6b	0.0c	0.2c	0.0b
	0.56	0.5	33.7ab	36.7a	0.0c	0.2c	0.0a	0.0b	0.0a	0.2b	0.0b	0.0b	0.0b	0.0c	0.0c	0.0b
Gallery	1.1	1	18.3bc	18.9b	3.6bc	4.6b	0.0a	0.0b	0.0a	0.0b	0.4b	0.8a	1.6b	1.2b	1.4ab	0.0b
	2.2	2	9.6c	16.9b	4.6b	2.8c	0.0a	0.0b	0.0a	0.0b	2.0a	0.6ab	1.2b	0.8bc	1.4ab	0.2b
Scotts OWC	2.2	2	17.2bc	36.4a	3.0bc	1.0c	0.0a	0.0b	0.0a	0.0b	1.0b	0.2b	1.0b	0.6bc	0.6bc	0.2b
	4.5	4	31.2ab	42.2a	1.4bc	0.6c	0.0a	0.0b	0.0a	0.0b	0.2b	0.0b	0.0b	0.4bc	1.0bc	0.0b

[z]Means with the same letter are not significantly different (SNK, $P \leq 0.05$). Only noteworthy weed efficacy results are shown.

[y]Data acquired July 5, 2002.

[x]Data acquired August 29, 2002.

[w]Fort Collins, CO.

[v]Grand Junction, CO.

Table 3. Effect of selected preemergent herbicides on dry weight and weed counts in container grown Daghestan sage 32 and 87 days following treatment at two locations.

Herbicide	Rate		Dry weight g/pot		Weed count[z] (no./pot)									
					Total weed count[y]		Annual bluegrass[y]		Barnyard grass[y]		Foxtail grass[y]		Sowthistle[x]	
	kg/ha	lb/A	FC[w]	GJ[v]	FC	GJ	FC	GJ	FC	GJ	FC	GJ	FC	GJ
Hand weed control	—	—	33.2a[z]	40.0a	0.0c	0.0d	0.0a	0.0b	0.0a	0.0c	0.0b	0.0a	0.0c	0.0b
Weedy control	—	—	5.9e	14.3e	17.8a	17.4a	0.8a	2.4a	0.6a	3.0a	5.2a	1.2a	0.0c	0.4ab
Barricade 65WG	0.73	0.65	13.2cde	26.1bcd	5.2bc	7.0b	0.0a	1.2b	0.2a	1.8b	1.0b	1.0a	2.0a	1.0ab
	1.46	1.3	14.7bcde	27.7bc	3.2bc	2.8cd	0.0a	0.0b	0.0a	0.4c	1.2b	0.8a	1.8ab	1.2a
Treflan 5G	4.5	4	20.4bcd	25.3cd	1.4c	2.8cd	0.0a	0.4b	0.2a	0.2c	0.2b	0.0a	1.0abc	0.4ab
	9.0	8	22.2bc	35.2ab	1.2c	0.0d	0.0a	0.0b	0.2a	0.0c	0.0b	0.0a	1.0abc	0.0b
BroadStar	0.28	0.25	22.2bc	33.2abc	0.6c	0.2d	0.0a	0.0b	0.2a	0.0c	0.2b	0.0a	0.0c	0.0b
	0.56	0.5	21.4bc	35.2ab	0.2c	0.0d	0.0a	0.0b	0.0a	0.0c	0.0b	0.0a	0.2c	0.0b
Gallery	1.1	1	5.4e	18.2de	6.6b	4.8bc	0.6a	3.0a	0.6a	1.0c	4.6a	0.8a	0.0c	0.0b
	2.2	2	9.8e	14.6e	3.8bc	2.4cd	0.6a	2.2a	1.2a	0.2c	1.2b	0.0a	0.0c	0.0b
Scotts OWC	2.2	2	11.6de	18.4de	4.4bc	1.0d	0.0a	0.0b	0.6a	0.2c	0.6b	0.0a	0.6bc	0.0b
	4.5	4	24.6b	34.6ab	1.0c	0.8d	0.0a	0.0b	0.0a	0.0c	0.0b	0.0a	0.2c	0.4ab

[z]Means with the same letter are not significantly different (SNK, $P \leq 0.05$). Only noteworthy weed efficacy results are shown.

[y]Data acquired July 5, 2002.

[x]Data acquired August 29, 2002.

[w]Fort Collins, CO.

[v]Grand Junction, CO.

Weed control at label rate for hopflower oregano from Treflan, BroadStar, and Barricade was 93, 91, and 85%. Weed control for Gallery and Scotts OWC was 69 and 46%, respectively. The 2× rate improved Scotts OWC efficacy. Scotts OWC had lower efficacy with a range of 69 to 93%, with Fort Collins 1× rate significantly reduced at 69%. Gallery had significantly reduced efficacy at both the 1× and 2× rates with a range of 46 to 67%. Zumelzú, Darré, Novo, and Bracamonte (30) also reported similar results for pendimethalin with an efficacy of 65% but different for trifluralin observing 83% efficacy compared to our 91.8%. The increased rate utilized in this study compared to Zumelzú et al. (30) could be the basis for increased efficacy. Gallery resulted in a significant decline in efficacy with annual bluegrass weeds at the 1× rate in Grand Junction, the 2× rate in Fort Collins, the 1× rate in Grand Junction for barnyard grass, and both the 1× and 2× rates in Fort Collins for foxtail. Barricade at the 2× rate in Grand Junction resulted in reduced efficacy with common groundsel and sowthistle.

General weed control efficacy for Daghestan sage plants showed weed control in the range of 59 to 100% (Table 3). Efficacy was significantly reduced with Barricade at the 1×

Table 4. Effect of selected preemergent herbicides on dry weight and weed counts in container grown skullcap 32 and 87 days following treatment at two locations.

Herbicide	Rate		Dry weight g/pot		Weed count[z] (no./pot)									
					Total weed count[y]		Barnyard grass[y]		Foxtail grass[y]		Barnyard grass[x]		Foxtail grass[x]	
	kg/ha	lb/A	FC[w]	GJ[v]	FC	GJ	FC	GJ	FC	GJ	FC	GJ	FC	GJ
Hand weed control	—	—	10.8a[z]	0.0a[u]	0.0b	5.0b[t]	0.0b	0.0b	0.0b	0.0b	0.2b	0.0b	0.0b	0.0a
Weedy control	—	—	1.8d	2.2a	20.2a	14.8a	1.4ab	1.6a	5.8a	0.8a	5.2a	1.2a	2.8a	0.4a
Barricade 65WG	0.73	0.65	3.0cd	5.9a	5.4b	7.8b	1.0ab	0.6ab	0.4b	0.0b	1.2b	0.6ab	0.0b	0.0a
	1.46	1.3	3.7cd	2.7a	2.2b	4.0b	0.0b	0.2b	0.2b	0.0b	0.2b	0.2ab	0.0b	0.0a
Treflan 5G	4.5	4	4.8bcd	6.5a	2.8b	4.6b	0.4ab	0.0b	0.4b	0.0b	0.4b	0.0b	0.0b	0.0a
	9.0	8	7.0abcd	12.1a	3.2b	4.0b	0.2ab	0.0b	0.2b	0.0b	0.4b	0.0b	0.0b	0.0a
BroadStar	0.28	0.25	10.1ab	0.0a	0.4b	4.2b	0.2ab	0.0b	0.0b	0.0b	0.4b	0.0b	0.0b	0.0a
	0.56	0.5	8.2abc	0.0a	0.4b	7.0b	0.0b	0.0b	0.4b	0.0b	0.2b	0.0b	0.2b	0.0a
Gallery	1.1	1	1.6d	4.6a	5.2b	2.0b	2.0a	0.8ab	1.8b	0.4ab	2.0b	1.0ab	1.6ab	0.4a
	2.2	2	1.7d	0.0a	4.2b	4.4b	1.4ab	1.0ab	1.8b	0.0b	1.8b	1.0ab	1.0b	0.0a
Scotts OWC	2.2	2	1.5d	3.1a	4.4b	2.2b	0.2ab	0.6ab	1.2b	0.0b	0.4b	0.6ab	0.8b	0.0a
	4.5	4	4.7bcd	4.5a	3.6b	5.0b	0.6ab	0.2b	1.2b	0.0b	1.0b	0.2ab	0.2b	0.0a

[z]Means with the same letter are not significantly different (SNK, $P \leq 0.05$). Only noteworthy weed efficacy results are shown.

[y]Data acquired July 5, 2002.

[x]Data acquired August 29, 2002.

[w]Fort Collins, CO.

[v]Grand Junction, CO.

[u]Crop failure on GJ Scutellaria control with no weeds.

[t]No grasses, only broadleaves were counted.

rate at Grand Junction and Gallery 1× at Fort Collins with 59 and 62%. The 1× rate efficacy was 96% for BroadStar. With Treflan, Scotts OWC, Gallery and Barricade weed control was 83, 75, 62, and 59% respectively. The 2× rate increased WC for Barricade and Gallery. Treflan and Scotts OWC at the 2× rate and BroadStar at both rates showed excellent weed control at both locations. Trifluralin, when tested at a lower rate of 2.2 kg ai/ha, resulted in moderate broadleaf and almost complete grass weed control (13). Gallery resulted in good control of foxtail at the 1× rate in Fort Collins and annual bluegrass at both rates in Grand Junction. Barricade had significant reduced efficacy for barnyardgrass at the 1× rate, for sowthistle at the 2× rate at Grand Junction, with both the rates at Fort Collins for sowthistle. Comparably, Henderson-Cole and Schnelle, using 1.1 and 4.5 kg ai/ha rates, gained complete control of crabgrass and pigweed (14). The lower application rate for 1× and differing weed species could explain the variable efficacy with sowthistle and barnyardgrass.

General weed control efficacy for skullcap plants showed weed control ranging from 47 to 98% for all herbicide treatments at both Fort Collins and Grand Junction (Table 4). Herbicide treatments in Fort Collins had higher efficacies (73–98%) than Grand Junction (47–86%). The difference could be attributed to the crop failure of skullcap at Grand Junction which provided less competition for resources in the container and more opportunity for weed establishment. Weed control at label rate was 78, 74, 71, 68, and 47% from Scotts OWC, Gallery, BroadStar, Treflan, and Barricade, respectively. Barricade efficacy improved with the 2× rate. Specifically, Gallery at the 1× rate had a significant reduction in weed control efficacy for barnyardgrass at Fort Collins. Gallery generally showed reductions in efficacy for both foxtail and barnyardgrass at the 1× rate, but was not statistically different. Previous research showed Gallery did not control crabgrass but did control broadleaf weeds, along with Barricade and pendimethalin controlling both weed types (10). Others have stated Gallery's strength is broadleaf weed control whereas Barricade, Treflan, and pendimethalin herbicides should be utilized for grass weed control and a few small seeded broadleaf weeds (2, 23). Mervosh (18) showed that flumioxazin gave longer weed control when compared to trifluralin, isoxaben, and pendimethalin herbicide combinations on *Spiraea*.

Among the plant growth parameters recorded, plant dry weight was the most sensitive indicator of plant performance. Other plant growth parameters, such as change in plant height and width, were recorded and found not to be statistically different. All herbicide treatments resulted in elimination or reduction in the number of weed seedlings without any visual phytotoxicity symptoms to the plants. Only noteworthy weed data is shown (Tables 1, 2, 3, 4). Prodiamine, pendimethalin, and trifluralin have been tested before on herbaceous plants such as daylily, hosta, and pansies at comparable rates and no phytotoxicity resulted (1, 29). Additionally Altland, Gilliam, Kessler, Wallace, and Riggs (1) and Staats and Klett (23) showed Gallery reduced dry weight and exhibited phytotoxicity. Other research on ornamental grasses with pendimethalin and prodiamine also reported no significant dry weight reduction (10). Mervosh (18) showed *Spiraea* treated with flumioxazin recovered from an initial reduction in shoot growth. Stamps and Chandler (25) reported phytotoxicity from flumioxazin primarily when applied to wet *Plumbago* foliage or at 4× label rates. Plant dry weight was greatly reduced by the presence of weeds as evidenced by the lower plant dry weights from the weedy treatment for Guizhou sage, hopflower oregano, Daghestan sage at both sites, and skullcap in Fort Collins (Tables 1, 2, 3, 4).

Generally, Guizhou sage plants resulted in no significant phytotoxicity and dry weight reduction from Barricade, Treflan, and BroadStar (Table 1). Scotts OWC had variable results with reductions from 0–50%. Dry weight reduction was most significant from Gallery with 35–81%. This reduction could indicate some phytotoxicity in spite of no visual symptoms since weed pressure was similar or less than other treatments.

Hopflower oregano plants showed no significant phytotoxicity and dry weight reduction from Barricade, Treflan, and BroadStar (Table 2). Zumelzú et al. incurred the same results in testing trifluralin on oregano (30). Scotts OWC 1× rate at Fort Collins resulted in a significant dry weight reduction of 53%. This is different from results of Zumelzú et al. (30) where testing of pendimethalin resulted in no dry matter reduction. This difference could be due to the fact that the active ingredient rate used by Zumelzú et al. (30) was half the rate used in this study. Gallery at 1× and 2× rates resulted in over 50% dry mass reduction at both Grand Junction and Fort Collins. Dry weights of hopflower oregano did not decrease with the 2× herbicide rate compared to the 1× rate for all herbicides with the exception of Gallery.

Daghestan sage plants showed significant phytotoxicity and dry weight reduction with every herbicide treatment at both locations with the least damage from BroadStar and Treflan.

At Fort Collins, significant declines in dry weight were observed from every herbicide treatment with a range of 25 to 83% (Table 3). Gallery treated plants were most affected with 70–83% reduction in dry weight. Grand Junction had 12 to 63% dry weight reduction. Significant reductions were from Barricade 1× and 2×, Treflan 1×, Scotts OWC 1×, and Gallery 1× and 2× rates. In other studies with salvia, shoot dry weights were reduced by Barricade with similar and higher rates (14) while minor damage was incurred at a lower rate of trifluralin (13).

Phytotoxicity and dry weights by the skullcap plants at Fort Collins showed a range of dry weight reduction from 6 to 86% from all herbicides, with the smallest reductions from BroadStar (Table 4). Significant reductions resulted from the 1× and 2× rates of Barricade, Gallery, and Scotts OWC as well as from the 1× rate of Treflan. Due to skullcap plant failure in the hand weed control, the 1× and 2× rates of BroadStar and the 2× rate of Gallery at Grand Junction, there was not sufficient data to draw conclusions from both locations. Consequently the statistical results showed no significant reduction in dry weight among the remaining treatments. Weeds grew well in these pots. Crop failure was likely due to either the saline irrigation water or the high ambient temperatures in Grand Junction, Colorado.

It was difficult to differentiate between the herbicide and weed effect on plant growth and dry weight accumulation with herbicide treated container plants. Weeds compete with container grown plants for water, nutrients, light, and space. The effect of weeds on crop growth parameters is seen clearly when the weedy treatment is compared to the no-weed control treatment (Tables 1, 2, 3, 4). No visual symptoms of phytotoxicity were observed on any plants

in this trial which indicated that competition by weeds for resources was the key factor impacting growth parameters such as dry weight.

The demand for new species and varieties of perennials (22) and the difficult task of producing healthy, weed free, saleable stock in a cost efficient manner warrants the use of preemergence herbicides in container production. Each herbaceous species responds independently to preemergence herbicides. In some cases, even a single weed in a container with an ornamental crop is important. A weed can detract from the marketability and will likely affect plant growth if not removed (10). The research described in this paper focuses on weed control using herbicides. The need to integrate herbicide applications with other weed control practices including using a weed-free growing medium and reduction of weed seed contamination is well recognized by nursery professionals.

Literature Cited

1. Altland, J.E., C.H. Gilliam, J.R. Kessler Jr., E.M. Wallace, and A.M. Riggs. 2001. Pansy tolerance to preemergence herbicides. J. Environ. Hort. 19:123–127.

2. Altland, J. 2003. Weed control in container crops. Oregon St. Univ. Ext. Service. Bul. EM 8823, pp. 1–15.

3. Altland, J.E., G.B. Fain, and K. Von Arx. 2004. Fertilizer placement and herbicide rate affect weed control and crop growth in containers. J.Environ. Hort. 22:93–99.

4. Berchielli-Robertson, D.L., C.H. Gilliam, and D.C. Fare. 1990. Competitive effects of weeds on the growth of container-grown plants. HortScience 25:77–79.

5. Bolques, A., J.G. Norcini, and J.H. Aldrich. 2003. Preemergence control of common groundsel (*Senecio vulgaris*). Proc. South. Nurs. Assoc. Res. Conf. 48:333–336.

6. Case, L.T., H.M. Mathers, and A.F. Senesac. 2005. A review of weed control practices in container nurseries. HortTechnology 15:535–545.

7. Cole, J.C. 1999. Propazine has little effect on growth of several containerized woody plant species. Hort Technology 9:198–202.

8. Czarnota, M.A., J.N. Barney, and L.A. Weston. 2001. Evaluation of weed control in three container grown ornamentals to flumioxazin. Proc. South. Nurs. Assoc. Res. Conf. 46:427–432.

9. Derr, J.F. 1994. Weed control in container-grown herbaceous perennials. HortScience 29:95–97.

10. Derr, J.F. 2002. Tolerance of ornamental grasses to preemergence herbicides. J. Environ. Hort. 20:161–165.

11. Fausey, J.C. 2003. Controlling liverwort and moss now and in the future. HortTechnology 13:35–38.

12. Fretz, T.A. 1972. Weed competition in container grown Japanese holly. HortScience 7:485–486.

13. Fretz, T.A. 1976. Herbicide performance on transplanted annual bedding plants. HortScience 11:110–111.

14. Henderson-Cole, J.C. and M.A. Schnelle. 1993. Effect of prodiamine and oxadiazon on growth of bedding plants and ground covers. J. Environ. Hort. 11:17–19.

15. Judge, C.A. and J.C. Neal. 2001. Preemergence control of *Microstegium vimineum*. Proc. South. Nurs. Assoc. Res. Conf. 46:448–450.

16. Mathers, H.M., L.T. Case, A.A. Stoven, S.B. Johansen, and J.A. Pope. 2003. Evaluation of ornamental weed control using microencapsulated herbicide treated bark mulch. Proc. South. Nurs. Assoc. Res. Conf. 48:351–353.

17. Mervosh, T.L. and J.F. Ahrens. 1998. Preemergence herbicides for container-grown perennials. Proc. Northeast Weed Sci. Soc. 52:131.

18. Mervosh, T.L. 2005. Comparison of granular herbicides for residual weed control in containers. Proc. Northeast Weed Sci. Soc. 59:35 (Abstract).

19. Nagy, F. 1977. Current weed control programmes for the large scale production of lavender, peppermint, tarragon and chamomile. Novenyvedelem 13:399–408.

20. Neal, J.C. 1997. Dinitroanaline herbicide comparison on container-grown herbaceous perennials. Proc. South. Nurs. Assoc. Res. Conf. 42:326–328.

21. Newby, A., C. Gilliam, J.Altland, C. Simpson, and G. Wehtje. 2003. Roundup pro and finale: Can they be used on woody landscape groundcovers? Proc. South. Nurs. Assoc. Res. Conf. 48:340–343.

22. Smith, L.J. and R.T. Taylor. 1997. Effects of preemergence-applied herbicides on container-grown perennials. Proc. South. Nurs. Assoc. Res. Conf. 42:312–314.

23. Staats, D. and J.E. Klett. 1993. Evaluation of weed control and phytotoxicity of preemergence herbicides applied to container-grown herbaceous and woody plants. J. Environ. Hort. 11:78–80.

24. Staats, D., D. Hillock, and J.E. Klett. 1998. Weed control and phytotoxicity of preemergence herbicides applied to container-grown herbaceous plants. HortTechnology 8:325–328.

25. Stamps, R.H. and A.L. Chandler. 2006. Plant size, growing medium and herbicide application method, formulation and rate influence phytotoxicity of flumioxazin to *Plumbago*. Proc. South. Nurs. Assoc. Res. Conf. 51:406.

26. Tallarico, J. and T. Voight. 2004. Weed control in ornamental grasses. Golf Course Management. Feb:143–147.

27. The Ohio State University. 2005. Controlling weeds in nursery and landscape plantings. Preemergence herbicides. Ohio State Univ. Ext. Bul. 867, pp 1. Accessed October 24, 2005. http://ohioline.osu.edu/b867/867_11.html.

28. Weed Science Society of America. 2002. WSSA Herbicide Nomenclature. Accessed October 11, 2005. http://www.wssa.net/herb&control/herbtab.htm.

29. Whitwell, T. and J. Kelly. 1989. Effects of preemergence herbicides on hosta and daylily. J. Environ. Hort. 7:29–31.

30. Zumelzú, G., C. Darré, R.J. Novo, and R.E. Bracamonte. 1999. Preemergent control of annual weeds in oregano (*Origanum vulgare* L.). Acta Hortic. 502:181–185.