WEED CONTROL

Stuart Warren
Section Editor and Moderator

Twenty-eight students competed In the Bryson L. James Student Research Competition and twenty-nine research projects were presented in poster form, which were displayed for review during the SNA Research Conference and Trade Show, this year. Their research is presented in the topical sections which follow and are designated as Student or Poster papers.

Postemergence Weed Control in Dormant Herbaceous Perennials

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Nature of the Work: During container nursery crop over-wintering, it is often not possible to apply preemergence herbicides because the covers may trap herbicide vapors, resulting in crop injury. Consequently, it is common to experience increased populations of winter annual weeds in over-wintered nursery stock. This is particularly true in the production of herbaceous perennials. Hand weeding plants in early spring is time consuming and expensive. This research was initiated to evaluate the potential safety and efficacy of postemergence, non-selective herbicides applied over dormant herbaceous perennials for winter weed control.

Container grown astilbe (*Astilbe* x *arendsii* 'Deuchland'), daylily (*Hemerocallis* sp. 'Naomi Ruth'), and hosta (*Hosta* spp. 'Aureomarginata') were potted in the spring of 1997 into 3 quart containers using a pine bark – based medium, and maintained by the cooperating nursery. In February 1998, astilbe, daylily and hosta plants were selected which were uniformly infested with hairy bittercress (*Cardamine hirsuta*), Carolina geranium (*Geranium carolinianum*) and horseweed (*Conyza canadensis*). On the day of treatment, astilbe and hosta were dormant but daylily had about 2 inches of new growth; bittercress was flowering, horseweed rosettes were 3 to 6 inches in diameter, and Carolina geranium rosettes were 4 to 10 inches in diameter. Herbicide treatments and application dates are in Table 1. Experimental design was a randomized complete block with four replications and three pots of each species in each replicate.

Results and Discussion: Both Reward and Scythe produced rapid control (Figure 1). Three weeks after treatment essentially complete control of all three weed species was obtained with Reward. Scythe controlled bittercress, but not horseweed and Carolina geranium. Weed control with Finale was significant (compared to the untreated control) at two weeks, and improved to essentially 100% by four weeks. After four weeks, Roundup-Pro did not control bittercress or Carolina geranium, but horseweed control was 80%. No differences were observed between one or two treatments, or between 30 and 90 gallons per acre (gpa) applications of Reward (Table 1). Seven weeks after treatment, all Reward and Finale treatments had provided excellent weed control, whereas weed control with Roundup-Pro and Scythe were not acceptable (Table 1). This trend continued for the remainder of the study (14 weeks). Ahrens and Mervosh (1) observed better control with Roundup-Pro, but applications were made later in the season. It is likely that in our test cool weather in January and February reduced the effectiveness of Roundup-Pro and Scythe.

Astilbe, daylily and hosta were visually evaluated every two weeks for 14 weeks. No significant injury was observed from any treatments. While Reward did produce some slight tip burn on emerged daylily, frosts in January and February produced more tip burn and herbicide injury was eliminated by those frosts. Similarly, Ahrens and Mervosh (1) reported no injury to dormant astilbe, hosta and daylily treated with Roundup-Pro. But, they did observe injury on other species that had emerged at the time of treatment. For this reason, we feel earlier season applications with contact-type herbicides, as demonstrated in this test, offer a safer alternative for winter weed control.

Significance to Industry: These results confirm our earlier observations (2) that winter applications of Reward will control many winter annual weeds without injury to dormant herbaceous perennials. When combined with a preemergence weed control program, postemergence applications of Reward or Finale over dormant herbaceous perennials could significantly reduce nursery and landscape dependence on hand weeding in the early spring. At this point in time, readers are cautioned that these are experimental treatments and are not currently labeled. However, efforts are currently underway to obtain labeling for this use.

Literature Cited:

1. Ahrens, J. F. and T. L. Mervosh. 1996. Postemergence weed control in dormant herbaceous perennials. Proc. Northeastern Weed Science Society 50:61.

2. Neal, J. C. and R. E. Wooten. 1998. Post-Emergent weed control in dormant herbaceous perennials. Proc. Northeastern Weed Science Society 52:16.

Table 1. Percent weed control with postemergence herbicides.

Herbicide	Appl. Rate	Appl. Dates	Spray Vol. (gpa)	Percent Control, 7 WAIT*		
				bittercress	Carolina geranium	horseweed
Untreated	0	--	--	0	0	0
Reward (diquat)	0.25 lb/A	Jan 22	30	97	100	100
Reward	0.25 lb/A	Jan 22 + Feb 13	30	97	100	100
Reward	0.25 lb/A	Jan 22	90	96	100	100
Reward	0.25 lb/A	Jan 22 + Feb 13	90	97	100	100
Scythe (pelargonic acid)	5% by volume	Jan 22 + Feb 13	90	85	45	67
Finale (glufosinate)	0.5 lb/A	Jan 13	90	96	100	100
Roundup-Pro (glyphosate)	0.5 lb/A	Jan 13	30	3	38	89
LSD (0.05)				14	23	14

*WAIT: Weeks after the initial treatment.

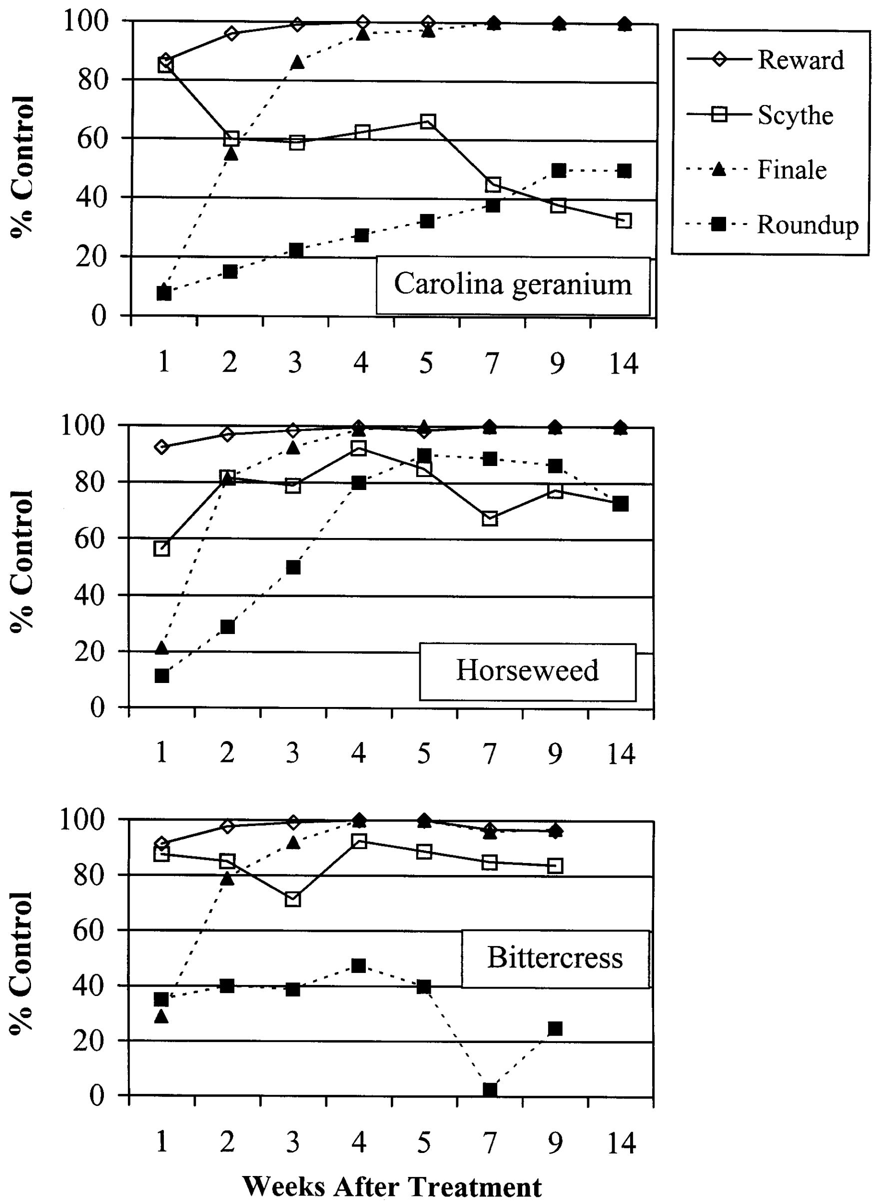

Fig. 1. Percent control of Carolina geranium, horseweed and bittercress with postemergence herbicides applied over dormant herbaceous perennials. Reward data were pooled for presentation.

Weed Control for Pot-In-Pot Production

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Nature of Work: The Pot-In-Pot (PNP) production system is increasing in popularity among nurseries in the Southeast. It is a hybrid of field and container production where plants are grown in containers, but placed in socket pots that are recessed in-ground in the field. There are several advantages to the PNP system for traditional field production nurseries including the opportunity for summer sales of nursery stock, eliminating costly summer digging, easier harvest of large nursery stock, and no overwintering structures are required.

Pre-emergence herbicide recommendations for weed control are not available for the PNP system. Many of the traditional pre-emergence herbicides used in field production are not labeled for container-grown ornamentals. For example, oryzalin (surflan) a commonly used herbicide in field production is not labeled for application on container-grown maples or ornamental pears. Traditional granular herbicides used in container production are not favorable due to the permanent spacing of containers in the PNP system, and the need for band application of herbicides. Alternative weed control strategies are being used. Geotextile material is installed as a ground cover controlling weeds adjacent to the socket pot, but does not control the weeds growing in the container. Post-emergence herbicides are applied to the growing container and the surrounding soil as an afterthought to weed germination and growth, but do not eliminate the weed problem. The objectives of this project were to monitor plant growth, observe phytotoxicity of PNP grown ornamentals, and to evaluate weed control of commonly used field pre-emergence herbicides.

This research project was conducted in two locations, in middle Tennessee and south Mississippi. At the Tennessee site, *Magnolia grandiflora*, southern magnolia, and *Acer rubrum* 'Franksred', Red Sunset red maple were potted in 15-gallon containers in March 1997 and placed in the PNP socket container. Field layout was eight feet between rows with two feet between containers in rows. Pre-emergence herbicides were band applied over the container media and the surrounding area encompassing about a one-foot strip along the perimeter of the growing container and area between the containers. Table 1 lists herbicides applied on 24 April and 21 July. A CO_2 backpack sprayer using 30 psi was used to apply herbicides at 25 and 20 GPA in Tennessee and Mississippi, respectively. At the Mississippi site, *Magnolia grandiflora* 'Little Gem' were potted into 25 gallon containers in June, 1995 and transferred to the PNP socket containers in April, 1997. Field layout consisted of blocks 18 ft wide with a 12 ft drive in between. Each block consisted of four rows with container spacing at 4.5 ft within and between rows. Row blocks were covered with woven polypropylene fabric. Table 2 lists herbicides sprayed on 6 May and 5 August, 1997.

Herbicide efficacy, reported as percent grass and broadleaf weed control, was recorded at 15, 30, 60, and 90 DAT (only 60 DAT shown) in Tennessee and 30, 60, 90, 120, 150, and 180 DAT in Mississippi (90 and 180 DAT shown). Weed populations were naturally occurring in both states, and data were combined from the magnolia and maple plots in Tennessee.

Results and Discussion: Plant growth of magnolia and Red Sunset maple grown in Tennessee was not affected by the use of pre-emergence herbicides with the exception of trees that had a 2x rate of Gallery. At the end of the growing season, plant height and or caliper was similar among treatments. There were no differences in growth of 'Little Gem' magnolia grown in Mississippi at the end of the growing season, and average height and caliper increase was 3.5 and 0.7 ft, respectively (data not shown).

At 60 DAT in Tennessee, grass control was acceptable (>80%) in most treatments with the exception of Surflan at 1/2x, Surflan+Gallery at 1x, Gallery at 1/2x, 1x, and 2x and Princep at 1/2x and 1x rates (Table 1). In the growing container, most of the broadleaf weeds were typical of traditional container production. Weeds present in the surrounding band around the containers were dandelions, wild geranium, crabgrass and yellow nutsedge. These weeds were small in number and at random locations in the test block.

In Mississippi, grass and broadleaf weed data was combined and reported as total weed control. At 90 DAT, only Pendulum at 2x, Surflan+Gallery at 1x, Surflan+Gallery at 2x, and Surflan+Princep at 2x+1x yielded significantly higher levels of weed control compared to the hand-weeded control (Table 2). However, all treatments except Surflan at 1/2x and 1x rates, Gallery at 1/2x rate, Princep at 1/2x and 1x rates, Surflan+Gallery at 1/2x rate, and the hand-weeded control yielded satisfactory weed control (>80%). At 180 DAT in Mississippi, all treatments yielded satisfactory weed control (Table 2). Predominate weed species were oxalis, yellow nutsedge, bittercress, prostrate spurge, and crabgrass.

Significance to Industry: Weed control strategies have been a challenge in the PNP system. This research data will provide information to assist nursery producers in developing pre-emergence herbicide programs for weed control in the PNP system. These data show that a number of pre-emergence herbicides currently labeled for use in field production provide effective and safe weed control in PNP production.

Acknowledgement: Thanks to Pleasant Cove Nursery, Rock Island, Tennessee and GreenForest Nursery, Inc., Perkinston, Mississippi for their cooperation and support of these projects.

Table 1. The effects of pre-emergence herbicide treatments on weed control at 60 DATZ in Tennessee.

Treatments	lb. ai/A	Rate	% Grass Control	% Broadleaf Control
Factor 65 WDG	0.75	1/2x	96[Y]	37
Factor 65 WDG	1.5	1x	100	88
Factor 65 WDG	3.0	2x	100	93
Gallery 75 DF	0.5	1/2x	58	8
Gallery 75 DF	1.0	1x	78	52
Gallery 75 DF	2.0	2x	48	30
Pendulum 60 WDG	1.0	1/2x	92	71
Pendulum 60 WDG	2.0	1x	92	81
Pendulum 60 WDG	4.0	2x	100	88
Princep L	1.0	1/2x	67	18
Princep L	2.0	1x	18	48
Surflan 4AS	1.0	1/2x	75	33
Surflan 4AS	2.0	1x	96	66
Surflan 4AS	4.0	2x	92	75
Factor + Gallery	0.75 + 0.5	1/2x + 1/2x	88	48
Factor + Gallery	1.5 + 1.0	1x + 1x	100	92
Factor + Gallery	3.0 + 2.0	2x + 2x	100	92
Pendulum + Gallery	1.0 + 0.5	1/2x + 1/2x	96	59
Pendulum + Gallery	2.0 + 1.0	1x + 1x	97	68
Pendulum + Gallery	4.0 + 2.0	2x + 2x	100	97
Surflan + Gallery	1.0 + 0.5	1/2x + 1/2x	78	45
Surflan + Gallery	2.0 + 1.0	1x + 1x	100	45
Surflan + Gallery	4.0 + 2.0	2x + 2x	100	64
Surflan + Princep	2.0 + 1.0	1x + 1/2x	100	54
Surflan + Princep	2.0 + 2.0	2x + 1x	96	62
Snapshot 2.5 TG	2.0	1x	95	47
Snapshot 2.5 TG	4.0	2x	100	93
Weedy Check	-	-	0	0
Weeded Check	-	-	0	0

[Z] Weed data combined from Red Sunset red maple and southern magnolia plots.

[Y] Means within columns separated by DMRT, $p<0.05$.

Table 2. The effects of pre-emergence herbicide treatments on weed control 90 and 180 DAT in Mississippi.

Treatment	ai/A	Rate	Weed control (%) 90 DAT	Weed control (%) 180 DAT
Factor	0.75	1/2x	84.8ab[z]	97.9a
Factor	1.5	1x	89.1ab	99.5a
Factor	3.0	2x	87.7ab	97.3a
Pendulum	1.0	1/2x	81.4ab	95.7a
Pendulum	2.0	1x	87.3ab	98.6a
Pendulum	4.0	2x	95.9a	99.1a
Surflan	1.0	1/2x	59.6ab	94.5a
Surflan	2.0	1x	42.3ab	97.5a
Surflan	4.0	2x	84.6ab	96.4a
Gallery	0.5	1/2x	49.6ab	94.3a
Gallery	1.0	1x	91.4ab	97.5a
Gallery	2.0	2x	83.6ab	96.5a
Princep	1.0	1/2x	65.5ab	93.4a
Princep	2.0	1x	75.1ab	97.7a
Factor+Gallery	0.75+0.5	1/2x+1/2x	90.5ab	99.1a
Factor+Gallery	1.5+1.0	1x+1x	94.1ab	99.5a
Factor+Gallery	3.0+2.0	2x+2x	89.1ab	99.2a
Pendulum+Gallery	1.0+0.5	1/2x+1/2x	83.2ab	97.4a
Pendulum+Gallery	2.0+1.0	1x+1x	87.7ab	98.8a
Pendulum+Gallery	4.0+2.0	2x+2x	88.2ab	98.2a
Surflan+Gallery	1.0+0.5	1/2x+1/2x	68.6ab	96.7a
Surflan+Gallery	2.0+1.0	1x+1x	92.1a	94.1a
Surflan+Gallery	4.0+2.0	2x+2x	97.7a	99.1a
Surflan+Princep	2.0+1.0	1x+1/2x	81.8ab	95.5a
Surflan+Princep	4.0+2.0	2x+1x	97.7a	98.5a
OH2	3.0	1x	83.2ab	99.6a
Hand-weeded check			21.4b	83.6a

[z]Means within columns having the same letter are not different according to Fisher's Protected Least Significant Difference ($p<0.05$).

Preemergence Herbicides for Perennials

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Nature of the Work: Few of the new herbaceous perennials being produced have appropriate herbicide labels. Information is not available for safe use of preemergence herbicides to control problem weeds in the production of container grown perennials in nurseries. Efforts over the past two years have focused on developing herbicide tolerance information for the newer species of herbaceous perennials.

Thirty (30) species were evaluated for tolerance to four preemergence herbicides at 1X and 4X normal use rates in 1996 (Table 1). Fourteen (14) species were observed for injury to five preemergence herbicides at 2Xuse rate in 1997 (Table 2). In all studies, uniform plugs were placed in 1gal pots and grown outside using a fertilizer and lime amended substrate of 85% pine bark and 15 % sand. Plants were watered daily using overhead irrigation and treatments were applied after plants were irrigated at least once.

Sprayable herbicides were applied utilizing a $C0_2$ sprayer delivering a volume of 30 gallons per acre. Granular herbicides were applied using a shaker can to a square meter of containers. After herbicide applications, plants were irrigated and observations were recorded for herbicide injury and plant recovery. Visual evaluations were made on a scale of 0 = no inj. and 100 = death monthly for 6 months after herbicide applications. These studies were conducted at the Clemson/Carolina Nursery Research Project located near Charleston, SC.

Results and Discussion: A number of species were tolerant to Gallery and Snapshot TG (Table 3) and had less than 20% injury. Species that were injured less than (20%) recovered and were marketable three months after application. There are notable differences in species tolerant to Gallery and Snapshot TG (Gallery + trifluralin). *Veronica latifolia*' Icicle', *Coreopsis verticillata* 'Zagreb' and Coreopsis verticillata 'Moonbeam' were tolerant to Gallery but not to Snapshot. Whereas, *Sedum, Scabosia, Ruellia , Monardia ,* and *Rudbeckia fuligida* 'Goldstrum' were tolerant to Snapshot TG but not to Gallery. Gallery WG is a sprayable formulation and Snapshot TG is a granular formulation. Injury from foliar absorption of Gallery WG may have accounted for the differences in response to Gallery and Snapshot TG.

Only 23 of the 44 species evaluated were tolerant to Rout applications. Regal OO was evaluated only in 1996 and 16 of the 30 species exhibited less than 20 % injured (Table 4). Pendulum and Factor were evaluated only in 1997 on 14 species. Six species were tolerant to Pendulum and ten species were tolerant to Factor (Table 5).

Significance to Industry: Using preemergence herbicides to reduce handweeding costs will decrease the production costs of new herbaceous perennials. However, tolerance information and labels are not available for many of the species now being produced. This research indicates that no preemergence herbicide can be used safely on all perennials but there are products that provide an acceptable degree of safety for several species.

Table 1. Herbaceous perennials evaluated for tolerance to preemergence herbicides in 1996 and 1997 at the Clemson/Carolina Nurseries Research Project located near Charleston, South Carolina.

Species evaluated - 1996	Herbicides and rates - 1996
Boltonia asteroides ‘Pink Beauty’	Gallery DF - 1 and 4 lbs ai/A
Boltonia asteroides ‘Snowbank’	Snapshot TG - 2.5 and 10 lbs ai/A
Chrysanthemum x *superbum* ‘Becky’	Rout - 3.0 and 12.0 lbs ai/A
Chrysanthemum x *superbum* ‘Snow Lady’	Regal OO - 3.0 and 12 lbs ai/A
Coreopsis verticillata ‘Rosea’	
Dianthus gratianopolitanus ‘Bath Pink’	
Dianthus gratianopolitanus ‘Firewitch’	
Dianthus plumarius ‘Spotti’	
Dianthus sp. ‘Mt. Mist Pink’	
Dianthus sp. ‘Mt. Mist White’	
Eupatorium fistulosm	
Gaura lindheimeri	
Helianthus angustifolius	
Hibiscus moscheutos ‘Disco Belle Pink’	
Hibiscus moscheutos ‘Disco Belle Rose’	
Monarda x ‘Marshall Delight’	
Pardancanda norisii	
Penstemon sp. ‘Husker Red’	
Phlox paniculata ‘Sandra’	
Rubeckia fulgida ‘Goldsturm’	
Rudbeckia maxima	
Rudbeckia nitida ‘Goldquelle’	
Sedum x ‘Autum Joy’	
Solidago rugosa ‘Firework’	
Solidago stricta	
Statice latifolia	
Tiarella sp. ‘Slickrock’	
Tiarella wherryi	
Tradescantia X *andersoniana* ‘Red Cloud’	
Veronica longifolia ‘‘Icicle’	

Table 2. Herbaceous perennials evaluated for tolerance to preemergence herbicides in 1997 at the Clemson/Carolina Nurseries Research Project located near Charleston, South Carolina.

Species evaluated in 1997	Herbicides and rates - 1997
Ceratostigma plumbagnoides	Gallery WG - 2.0 lb ai/A
Chelone lyonii 'Hot Lips'	Snapshot TG - 5.0 lb ai/A
Chrysogonum virginianum 'Allen Bush'	Rout - 6.0 lbs ai/A
Coreopsis verticillata 'Moonbeam'	Factor - 2.0 lbs ai/A
Coreopsis verticillata 'Zargreb'	Pendulum - 4.0 lbs ai/A
Cuphea hyssop 'Allison'	
Filipendula hexapetals	
Nepeta sp. 'Dawn to Dusk'	
Penstemon sp. 'Husker Red'	
Ruellia brittonia 'Katie'	
Scabiosa columbaria 'Butterfly Blue'	
Sedum sp. 'Matrona'	
Stachys byzantina 'Big Ears'	
Veronica spicata. 'Red Fox'	

Table 3. Herbaceous perennials with less than 20% injury to Gallery and Snapshot TG preemergence herbicides evaluated 1996 and 1997 at the Clemson/Carolina Nurseries Research Project located near Charleston, South Carolina.

Gallery (< 1.0 lb ai/A)	Snapshot TG (< 2.5 lb ai/A)
Boltonia asteroides 'Pink Beauty'	*Boltonia asteroides* 'Pink Beauty'
Boltonia asteroides 'Snowbank'	*Boltonia asteriudes* 'Snowbank'
Coreopsis verticillata 'Zagreb'	*Coreopsis verticillata* 'Rosea'
Coreopsis verticillata 'Moonbeam'	*Chelone lyonii* 'Hot Lips'
Coreopsis verticillata 'Rosea'	*Cuphea hyssop* 'Allison'
Cuphea hyssop 'Allison'	*Dianthus gratianopolitanus* 'Bath Pink'
Dianthus gratianopolitanus 'Bath Pink'	*Dianthus gratianopolitanus* 'Firewitch'
Dianthus gratianopolitanus 'Firewitch'	*Dianthus plumarius* 'Spotti'
Dianthus plumarius 'Spotti'	*Dianthus* sp. 'Mt. Mist Pink'
Dianthus sp. 'Mt. Mist Pink'	Dianthus sp. 'Mt. Mist White'
Dianthus sp. 'Mt. Mist White'	*Eupatorium fistulosm*
Eupatorium fistulosm	*Filipendula hexapetals*
Filipendula hexapetals	*Gaura lindheimeri*
Gaura lindheimeri	*Helianthus angustifolius*
Helianthus angustifolius	*Monarda* X 'Marshall Delight'
Hibiscus moscheutos 'Disco Belle Pink'	*Nepeta* sp. 'Dawn to Dusk'
Hibiscus moscheutos 'Disco Belle Rose'	*Pardancanda norisii*
Nepeta sp. 'Dawn to Dusk'	*Rudbeckia fulgida* 'Goldstrum'
Pardancanda norisii	*Rudbeckia maxima*
Phlox paniculata 'Sandra'	*Ruellia brittonia* 'Katie'
Rudbeckia maxima	*Scabiosa columbaria* 'Butterfly Blue'

Ruellia brittonia 'Katie'	*Sedum* sp. 'Matrona'
Sedum sp. 'Matrona'	*Solidago rugosa* 'Firework'
Statice latifolia	*Statice latifolia*
Tradescantia X *andersoniana* 'Red Cloud'	*Tradescantia* X *andersoniana* 'Red Cloud'
Veronica latifolia 'Icicle'	

Table 4. Herbaceous perennials with less than 20% injury to Rout and Factor preemergence herbicides evaluated 1996 and 1997 at the Clemson/Carolina Nurseries Research Project near Charleston, South Carolina.

Rout (< 3.0 lb ai/A)	Factor (< 1.5 lb ai/A)
Boltonia asteroides 'Pink Beauty'	*Chrysogonum virginianum* 'Allen Bush'
Boltonia asteroides 'Snowbank'	*Coreopsis verticillata* 'Zagreb'
Coreopsis verticillata 'Zagreb'	*Cuphea hyssop* 'Allison'
Coreopsis verticillata 'Moonbeam'	*Nepeta* sp. 'Dawn to Dusk'
Coreopsis verticillata 'Rosea'	*Penstemon* sp. 'Husker Red'
Chelone lyonii 'Hot Lips'	*Ruellia brittonia* 'Katie'
Cuphea hyssop 'Allison'	*Scabiosa columbaria* 'Butterfly Blue'
Dianthus gratianopolitanus 'Bath Pink'	*Sedum* sp. 'Matrona'
Dianthus gratianopolitanus 'Firewitch'	*Stachys byzantina* 'Big Ears'
Dianthus plumarius 'Spotti'	*Statice latifolia*
Dianthus sp. 'Mt. Mist Pink'	
Dianthus sp. 'Mt. Mist White'	
Eupatorium fistulosm	
Filipendula hexapetals	
Gaura lindheimeri	
Helanthus angustifolius	
Monarda X 'Marshall Delight'	
Nepeta sp. 'Dawn to Dusk'	
Pardancanda norisii	
Penstemon sp. 'Husker Red'	
Phlox paniculata 'Sandra'	
Solidago rugosa 'Firework'	
Statice latifolia	

Table 5. Herbaceous perennials with less than 20% injury to Regal OO and Pendulum preemergence herbicides evaluated 1996 and 1997 at the Clemson/Carolina Nurseries Research Project near Charleston, South Carolina.

Regal OO (< 3.0 lb ai/A)	Pendulum (< 3.0 lb ai/A)
Boltonia asteroides 'Pink Beauty'	*Chrysogonum virginianum* 'Allen Bush'
Boltonia asteriudes 'Snowbank'	*Nepeta* sp. 'Dawn to Dusk'
Coreopsis verticillata 'Rosea'	*Penstemon* sp. 'Husker Red'
Dianthus gratianopolitanus 'Bath Pink'	*Scabiosa columbaria* 'Butterfly Blue
Dianthus gratianopolitanus 'Firewitch'	*Sedum* sp. 'Matrona'
Dianthus plumarius 'Spotti'	*Stachys byzantina* 'Big Ears'
Dianthus sp. 'Mt. Mist Pink'	
Dianthus sp. 'Mt. Mist White'	
Eupatorium fistulosm	
Gaura lindheimeri	
Helanthus angustifolius	
Monarda X 'Marshall Delight'	
Pardancanda norisii	
Phlox paniculata 'Sandra'	
Solidago rugosa 'Firework'	
Statice latifolia	

Postemergence Control of Bittercress
(Student)

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Nature of Work: Weed control is an essential part of the container production process. Most weeds are controlled with a program that includes multiple applications of preemercence applied herbicides, however, no chemical program provides complete control. Weed populations tend to increase late in the season as herbicide dissipation weakens the chemical barrier. Weed control is also lacking early in the year after plants are removed from overwintering. Bittercress (*Cardamine spp*.) has been identified as one of the most prolific weeds in containers that lack adequate weed control (1). The objective of this study was to evaluate postemergence herbicides for control of bittercress in container grown liriope (*Liriope muscari*).

The first test was conducted on June 25, 1997, at the Mobile Experiment Station in Mobile, AL. Variegated liriope (*Liriope muscari* 'Variegata') liners were selected with uniform populations of bittercress that ranged from 0.2 to 0.8 in. tall. Plants were treated with the following herbicides: Manage (halosulfuron) at 0.03, 0.06, and 0.12 lb ai/A; Image (imazaquin) at 0.25, 0.50, and 1.00 lb ai/A; Action (fluthiacet-methyl) at 0.14, 0.28, and 0.56 oz. ai/A; and Resource (flumichlorac pentyl ester) at 0.027, 0.054, and 0.108 lb ai/A. Manage and Image are postemergence herbicides used for nutsedge control, which in other studies caused no observable phytotoxicity to liriope (2,3). Action and Resource are experimental postemergence herbicides used for broadleaf weed control in corn. All treatments consisted of 10 single plant replicates in a completely randomized block design.

Data collected included weed counts at 15 and 50 days after treatment (DAT), top dry weight (TDW) of both the bittercress and liriope at 50 DAT, and a liriope phytotoxicity rating from 1 to 5 (1 = no damage, 2 = slight damage, 3 = moderate damage, 4 = severe damage, 5 = dead plant) at 15 DAT.

The second test was conducted at the Mobile Experiment Station in Mobile, AL. Container grown variegated liriope were over seeded with bittercress on September 16, 1997. Containers were treated with the following herbicides on October 1, 1997, when the bittercress were 0.4 to 0.8 in. tall: Manage at 0.0075, 0.015, and 0.03 lb ai/A; Image at 0.0625, 0.125, and 0.25 lb ai/A; Trimec Southern (MCPP + 2,4-D + dicamba) at

1.0, 2.0, and 4.0 pt./A; and Roundup (glyphosate) at 0.0.075, 0.15, and 0.30 lb ai/A. Manage and Image demonstrated effective weed control with some signs of phytotoxicity in the first test. Therefore, they were used again in the second test at lower rates. Trimec Southern was chosen because of its selectivity against broadleaf weeds in grasses and other monocots. Roundup was selected to determine if low rates could control the bittercress without damaging the liriope. All treatments consisted of 10 single plant replicates in a completely randomized block design.

Data collected included % bittercress killed at 9 and 20 DAT, top fresh weight (TFW) of the bittercress at 30 DAT, a phytotoxicity rating from 1 to 5 on the liriope at 9 DAT, and a bibb count on the liriope the following spring (May, 1998). Data from both tests were subjected to analysis of variance and Duncan's Multiple Range test using SAS v6.12.

Results and Discussion: At 15 DAT, all rates of Manage and the two higher Image rates resulted in bittercress weed counts lower than the non-treated control. However, these treatments also resulted in the most phytotoxicity; characterized by necrosis and leaf rotting in the plant crown. All treatments except for the lowest rate of Resource resulted in phytotoxicity levels higher than the control.

At 50 DAT, all rates of Manage and Image resulted in complete bittercress control. However, these treatments also resulted in lower TDW of liriope than the non-treated control. Based on data from the first test, it was concluded that Manage and Image were effective at controlling bittercress but lower rates would be needed to prevent liriope phytotoxicity.

Results of the second test with lower rates of Manage and Image resulted in excellent weed control as in experiment one, while phytotoxicity ratings were similar to non-treated controls (Table 1). Bittercress control was also excellent with all rates of Trimec Southern. The two higher rates of Roundup provided 57% and 61% control respectively, while the low rate of Roundup provided only 10% control. Only the highest Roundup rate caused greater phytotoxicity than the non-treated controls. Visual inspection revealed light to moderate crown necrosis on the liriope treated with the low Roundup rate, and severe crown necrosis on the plants treated with the higher Roundup rates. Manage and Image treated plants had similar bibb numbers to control plants the following spring (1998).

Significance to Industry: Our results show that effective post emergence bittercress control can be obtained with little or no phytotoxicity by using postemergence herbicides. Manage or Image at low rates controlled bittercress with no phytotoxicity to liriope. Roundup resulted in poor control of bittercress and caused high rates of phytotoxicity. Trimec Southern gave excellent control of bittercress, but it also caused phytotoxicity to the liriope.

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Table 1. Herbicide effect on % control of bittercress, fresh weight of bittercress (30 DAT), phytotoxicity to liriope (30 DAT), and liriope bibb count (May, 1998).

Herbicide	Rate lb ai/A	% Bittercress Control 9 DAT	% Bittercress Control 20 DAT	Bittercress fresh weight (g)	Liriope phytotoxicity[z]	Liriope bibb count[y]
Manage	0.0075	57 b	86 a	0.95 cd	1.2 cd	5.1 ab
Manage	0.015	89 a	100 a	0.17 d	1.4 cd	5.7 a
Manage	0.03	96 a	98 a	0.41 cd	1.6 bcd	4.3 abc
Image	0.0625	93 a	97 a	0.32 d	1.1 d	4.7 abc
Image	0.125	97 a	100 a	0.00 d	1.4 cd	6.2 a
Image	0.25	99 a	100 a	0.10 d	1.6 bcd	5.5 ab
Trimec Southern	0.14	99 a	96 a	0.06 d	2.1 ab	3.4 bc
Trimec Southern	0.28	100 a	96 a	0.02 d	1.4 cd	4.2 abc
Trimec Southern	0.56	100 a	100 a	0.00 d	1.6 bcd	2.8 c
Roundup	0.075	0 d	10 c	3.16 b	1.5 cd	4.6 abc
Roundup	0.15	18 c	61 b	2.10 bc	2.4 a	4.4 abc
Roundup	0.3	24 c	57 b	1.50 cd	1.7 bc	4.5 abc
Control		4 d	0 c	11.34 a	1.7 bc	4.6 abc

[z] Scale from 1 to 5 where 1 = no damage; 2 = slight damage; 3 = moderate damage; 4 = severe damage; 5 = plant death.
[y]Data taken the following spring (1998).

Simazine Uptake and Distribution by *Canna hybrida* 'King Humbert' - Implications for Phytoremediation -

(Student)

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Nature of Work: Phytoremediation is the use of plants for detoxifying environmental sites contaminated with pollutants. This technology exploits the ability of plants to extract and/or mineralize contaminants in the surrounding environment. Phytoremediation of organic pollutants may occur by: 1) direct root uptake and subsequent accumulation of nonphytotoxic metabolites in plant tissue, 2) direct foliar uptake of volatile contaminants from the surrounding air by foliage, and 3) release of exudates and enzymes that enhance biochemical transformations and/or mineralization due to microbial activity in the rhizosphere (Schnoor et al., 1995). Phytoremediation may be a useful technique for removing certain pesticides such as simazine from water runoff or sprayer-tank rinsates at ornamental plant nurseries. Ornamental plants such as cannas may be useful for such remediation.

Simazine is labeled for control of many annual weeds in turfgrass and ornamentals. Simazine is moderately soluble in water and is not volatile. The USDA Soil Conservation Service has classified this compound as a likely candidate for losses by surface runoff and leaching (Kenna, 1995). The objective of this research was to evaluate the uptake and distribution of simazine from water by *Canna hybrida* 'King Humbert'.

Test plants were propagated by rooting tuber cuttings from original stock plants in a glasshouse using Fafard germination mix (Anderson, SC). Plants were watered and fertilized as needed. Approximately 2 to 3 weeks before tests were initiated, plants were transferred from potting media in the glasshouse to hydroponics in the lab using 10% Hoagland's nutrient media. Plants evaluated weighed approximately 12-20 g (0.42-0.71 oz) and were approximately 17-25 cm (6.7-9.8 inches) tall (measured from tuber to tip of center leaf).

Approximately 46 µCi of ^{14}C-ring-labeled simazine was dissolved overnight in 10% Hoagland's nutrient media. This was equivalent to a concentration of 0.243 mg/L (243 ppb). Previous studies showed that this concentration was not toxic to the plants. Twelve 250 mL sidearm vacuum flasks were each filled with 275 mL of the spiked nutrient media. Eight control plants were exposed to non-spiked nutrient media in a similar fashion. The side-arms of the exposure flasks were equipped with 1-way valves that allowed movement of gases from the outside of the flask to the inside, but not vice versa. Individual plants were held in place (with roots submerged in the spiked or non-spiked nutrient media) by # 6 silicon stoppers with holes bored through the tops, and a slit along the side. Stoppers were wrapped around individual plant stems and sealed using Qubitac (Qubit Systems; Quebec, Canada) nontoxic, nonreactive putty. Once plants were secured in the exposure flasks, they were transferred to a Conviron CMP3244 environmentally controlled growth chamber under the following conditions: light intensity, 375 ± 25 $\mu mol\ m^{-2}s^{-1}$ generated by fluorescent and incandescent lamps; photoperiod: 16 h light: 8 h dark; relative humidity: 60%; and temperatures: 25°C (77°F) light: 22°C (71.6°F) dark. Water transpired through the plants was replenished with distilled, deionized water using a 60 mL syringe. Water use was recorded daily.

On days 1, 3, 5, and 7, 3-exposed and 2-control plants were randomly selected for harvest. Plant roots were rinsed in running tap water for 45 seconds and blotted dry. Plants were then dissected into individual leaves, stems, tubers, and roots. Organs were weighed and wrapped in aluminum foil, flash frozen using liquid nitrogen, and stored at -80(C. At the time of analysis, plant organs were freeze dried, weighed, and combusted using a R. J. Harvey Biological Oxidizer at 900°C (1652°F) for 3 min. $^{14}CO_2$ generated by combustion was captured using R. J. Harvey $^{14}CO_2$ cocktail. The captured $^{14}CO_2$ content was analyzed using a Beckman LS 6500 Liquid Scintillation Counter. Each sample was counted for 8 min in the dpm (disintegration per minute) mode.

Results and Discussion: Increasing ^{14}C-simazine uptake was observed over the 7 d exposure period. The majority of activity in each plant was distributed primarily in the leaves after 3 d exposure (Figure 1). ^{14}C-simazine uptake was directly proportional to the total amount of water transpired by each plant. Uptake by the cannas accounted for 15, 37, 52, and 69% of the original activity after 1, 3, 5, and 7 d exposure (Figure 1). The assumption that the activity detected within each plant was due to uptake of the parent compound from solution was valid since high pressure liquid chromatographic analysis confirmed that the ^{14}C-simazine remaining in solution after each harvest had not degraded. One question that this research did not address is the fate of the simazine once it is in the plant. This was not possible because of the destructive nature of combusting the samples. However, it is likely that some metabolism occurred. Burauel and Fuhr (1988) suggested that plant metabolism was responsible for the greater degree of simazine mineralization in their soil following uptake by *Maize* and desiccation of the plant. They suggested that the simazine was more readily degradable by microorganisms following plant metabolism (Burauel and Fuhr, 1988). Likely metabolic products include hydroxy-simazine (Beyton et al., 1972; Otto et al., 1979) and glutathione conjugated simazine (Beyton et al., 1972).

Although these results indicate that the King Humbert canna may be useful for removing simazine from contaminated water, it is important to realize that in this situation, all of the simazine was in solution. However, this is not likely to be the case under field conditions with an organic substrate. Sorption to soils and organic matter in the field will likely decrease the bioavailability of simazine for uptake by the plants. However, in a gravel-based constructed wetland, bioavailability and potential uptake by the plants will be maximized. Future work will evaluate the actual phytoremedial ability of the King Humbert canna and other ornamental species in gravel-based, constructed wetlands at Clemson University.

Significance to Industry: Pesticide use by the ornamental horticulture industry is necessary for the production of pest-free, high quality, premium return ornamental crops. Establishment of constructed wetlands in areas subject to high pesticide loadings in water (such as at pesticide sprayer wash stations) may reduce environmental threats to human and wildlife populations that might otherwise be exposed. *Canna hybrida* 'King Humbert' appears to be a good candidate for establishment in these constructed wetlands based on its uptake of simazine. In addition to filtering contaminated water generated by pesticide applications, the nursery industry may also benefit from increased interest in and production of this and other similar crops under a new marketing strategy.

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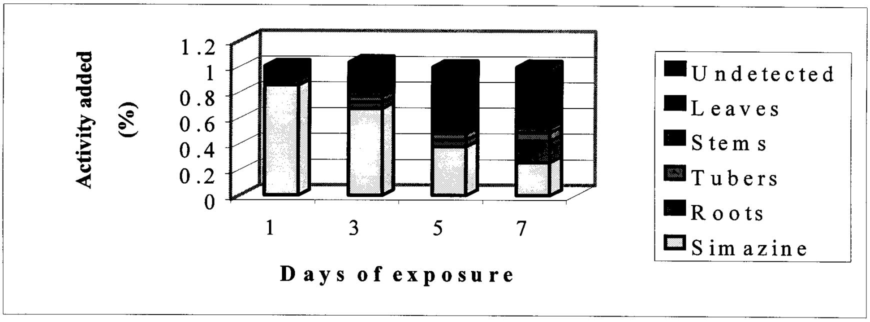

Figure 1. Mass balance for ^{14}C-simazine uptake by *Canna hybrida* 'King Humbert'. "Simazine" = activity remaining in exposure solutions.

Taxus Response to Differential Concentration and Timing of Pendimethalin Application

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Nature of Work: Suspected herbicide phytotoxicity injury in the nursery industry initiated our interest in this project. Industry reports indicated that phytotoxicity damage had occurred when pendimethalin was used for weed control in the production of *Taxus*. Initial reports stated foliar death occurred where herbicide application had resulted in foliage contact. Reports have indicated plant injury occurred, but not total plant loss. Our interest was to determine if pendimethalin application was the cause of *Taxus* injury and if so, was it due to application at early growth stage or rate or formulation of material applied. An established field planting of 24 - 30 inch *Taxus media "Densiformis"* was used for this experiment. Treatment plots measured 12 ft. by 7 ft., with three plants per plot. Five treatments were used on three spray dates, for a total of fifteen treatments replicated three times. The treatments were: pendimethalin(Pendulum) 3.3 EC at 2, 4, and 8 lbs. active ingredient per acre(AIA); pendimethalin(Pendulum) 60WG at 4 lbs. AIA; and a control. The spray dates were: April 28, May 13, and May 30, 1997. Treatments were applied over the top of the plants using a CO_2 pressurized back-pack sprayer calibrated to 26 GPA using 8004 nozzles at 30 psi at the boom. New growth on the *Taxus* was approximately one inch in length on April 28, 1997.

Results and Discussion: Plant phytotoxicity was measured on a scale from 0-10 (0 representing no phytotoxicity and 10 representing plant death). Spray date one was evaluated on May 12, spray date one and two were evaluated on June 3, spray date one, two & three were evaluated on June 18. Evaluation on July 7 was not performed because no visible change in foliage was observed. Once dead foliage was observed, evaluations were continued for all three spray dates on August 28 and September 30, 1997.

Phytotoxicity during the May 12, June 3, and June 18 ratings consisted of slight foliar discoloration. No change had occurred by July 7 and the plot was not rated. This was different from what was reported in the nursery industry where foliar death was reportedly occurring within weeks. By mid August, foliar injury had become more pronounced and ratings were resumed on August 28 and September 30. Phytotoxicity increased in intensity as the season progressed. Final level of damage was still unknown on Sept. 30. With the EC formulation, phytotoxicity increased as the rate increased from 2 to 8 lbs.(Table 1). Although the WG formulation initially caused more severe discoloration during the first ratings, by the Sept. rating damage was less than that of the EC formulation. Besides causing foliar discoloration, the most severely affected plants also exhibited stunted growth of newly emerged shoot tissue.

This class of herbicides is known to influence root system growth and has strong adsorption to soil. Little information is available on foliar uptake or injury associated with woody landscape plants. For turfgrass, pendimethalin will be retained on and within the foliage(1). Exposure to sunlight and high temperatures are thought to contribute to initial pendimethalin dissipation(1). Temperatures were below normal for Lexington, KY during our initial treatment. Varying levels of rainfall occurred immediately after application on each treatment date(Table 2). Rainfall apparently had limited influence on *Taxus* injury and growth; however, the influence of mild temperatures is unknown. Mild temperatures may contribute to the slow development of severe phytotoxicity. Photos were taken September 16, 1997.

Significance to Industry: Pendimethalin, at levels of 2 to 8 lbs./A, may inhibit new shoot development for cutting propagation in *Taxus*. The slow rate of phytotoxicity symptom development could mean that cuttings taken from treated plants may fail after entering the propagation cycle.

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Table 1. Phytotoxicity Ratings on *Taxus* after treatment with Pendimethalin.

Treatment	Form	Rate and Unit	Application Date	May 12 Rating	June 3 Rating	June 18 Rating	August 28 Rating	September 30 Rating
Pendulum	3.3 EC	2.0 lb AIA	April 28	0.0 b	0.1 b	0.4 abc	0.6 fg	1.1 e
Pendulum	3.3 EC	4.0 lb AIA	April 28	0.1 ab	0.1 b	0.5 ab	1.1 def	1.4 de
Pendulum	3.3 EC	8.0 lb AIA	April 28	0.3 ab	0.1 b	0.5 ab	1.9 cd	2.3 c
Pendulum	60 WG	4.0 lb AIA	April 28	0.4 a	0.4 a	0.7 a	1.0 def	1.1 e
Control			April 28	0.0 b	0.0 b	0.0 e	0.0 g	0.0 f
Pendulum	3.3 EC	2.0 lb AIA	May 13		0.1 b	0.1 de	1.9 cd	2.1 cd
Pendulum	3.3 EC	4.0 lb AIA	May 13		0.1 b	0.2 bcde	3.3 a	3.9 ab
Pendulum	3.3 EC	8.0 lb AIA	May 13		0.2 ab	0.2 bcde	3.0 ab	4.3 ab
Pendulum	60 WG	4.0 lb AIA	May 13		0.2 ab	0.4 abc	1.2 cdef	1.1 e
Control			May 13		0.0 b	0.0 e	0.0 g	0.0 f
Pendulum	3.3 EC	2.0 lb AIA	May 30			0.3 bcd	1.2 cdef	1.9 cd
Pendulum	3.3 EC	4.0 lb AIA	May 30			0.2 cde	1.7 cde	3.7 b
Pendulum	3.3 EC	8.0 lb AIA	May 30			0.4 abc	2.1 bc	4.7 a
Pendulum	60 WG	4.0 lb AIA	May 30			0.3 bcde	0.8 efg	1.0 e
Control			May 30			0.0 e	0.0 g	0.0 f

Column means followed by different letters are significantly different (P=0.05; ANOVA)

Table 2. Weather data for Lexinton, KY for the seven day period following herbicide application

Treatment Time	Date	Air Temp. Max	Air Temp. Min.	Precip.
Treat. Date One	April 28	56	47	T
	April 29	67	40	
	April 30	78	46	0.32
	May 1	57	47	0.04
	May 2	76	46	0.19
	May 3	61	47	1.03
	May 4	64	41	
Treat. Date Two	May 13	61	41	T
	May 14	71	46	0.09
	May 15	61	42	0.06
	May 16	60	33	
	May 17	73	48	0.08
	May 18	84	61	0.02
	May 19	82	64	0.37
Treat. Date Three	May 30	75	54	0.06
	May 31	66	63	2.85
	June 1	70	62	0.53
	June 2	79	52	0.07
	June 3	72	57	0.01
	June 4	65	53	
	June 5	67	53	T

T = trace

Effects of Herbicides on Selected Perennials
(Poster)

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Nature of Work: American gardeners are discovering the beauty and special interest that perennials can bring to their created landscapes. Nurseries are producing more species each year for sale at the wholesale and retail levels to meet the increasing demand for these types of plants. For this reason, it is important for the nursery grower to have herbicides that are labeled for use with this increasing list of commercially grown perennials, particularly as labor costs rise and hand weeding becomes a less than profitable option. The objective of the study was to evaluate the tolerance of selected containerized perennials to topical application of preemergent herbicides.

On May 14, 1997, uniform plugs were potted in 3.4 liters (1-gal.) containers with a pinebark:sand (6:1, v:v) mix amended with dolomitic limestone and Mircomax at 5.0 lb. and 1.5 lb. per cubic yard, respectively. Plants were top-dressed at potting with one TBL. Osmocote 14-14-14 and irrigated daily with 0.5 inch of water applied through overhead sprinkler irrigation. The species were: purple coneflower (*Echinaceae purpurea* 'Bravado'); daylily (*Hemerocallis* x 'Sammy Russell'); shasta daisy (*Leucanthemum maximum* 'Snow Lady'); and Yarrow (*Achillea millefolium* 'Pink Deb'). Herbicide treatments were: Factor 65WG at 1.5, 3.0, and 6.0 lbs. ai/A; Gallery 75 DF at 0.5, 1.0, and 2.0 lbs. ai/A; Pendulum 2G at 2.0, 4.0, and 8.0 lbs. ai/A; Pennant 5G at 3.0, 6.0, and 12.0 lbs. ai/A; and Snapshot 2.5TG at 2.5, 5.0, and 10.0 lbs. ai/A. Treatments were applied over the top of the containerized perennials on May 21, 1997 utilizing either a CO_2 backpack sprayer at 25 GPA or a hand-held shaker. On May 22, 1997, the daylilies were overseeded with prostrate spurge (*Euphorbia supina*) and the purple coneflower with crabgrass (*Digitaria sanguinalis*). At each observation date (15, 30, and 60 DAT), germinated weeds were counted and removed in the herbicide treatments and the weeded control. In the weedy control, the weeds were counted but not removed.

Results and Discussion: Shasta daisy (*Leucanthemum maximum* 'Snow Lady') showed slight stunting and injury at 15 days after treatment (DAT) from Factor, Gallery, Pennant, and Snapshot (Table 1). By 30 DAT, shasta daisy had grown out of the initial damage caused by these herbicides and continued to be healthy through 60 DAT. Severe damage was observed on shasta daisy at 15 DAT from Pendulum 2G at 2.0 and 4.0 lb. ai/A and plants showed prolonged phytotoxicity through 30 DAT and 60 DAT. Shoot dry weight (60 DAT) from Gallery 75 DF at 2.0 lb. ai/A and Pendulum 2G at 2.0 and 4.0 lb. ai/A were approximately _ the weight of the other herbicide treatments, indicating the higher herbicide rates had stunted the plants growth.

Purple coneflower (*Echinacea purpurea* 'Bravado') had slight to moderate injury at 15 DAT with all herbicide treatments. By 30 DAT the plants had grown out of the herbicide damage. At 60 DAT, shoot dry weights had no concernable difference between herbicide treatments (data not shown). However, the dry weight of the weedy control was 1/3 the weight of the weeded control. This is most likely due to the increased competition between the purple coneflower and the crabgrass in the weedy control.

Daylily (*Hemerocallis* x 'Sammy Russell') had slight foliar injury at 15 DAT with all herbicide treatments (data not shown). By 30 DAT, plants had grown out of the herbicide damage.

Yarrow (*Achillea millefolium* 'Pink Deb') were not adversely affected by herbicide treatments in this study and were rated healthy for all treatments (data not shown).

Factor, Pendulum, Pennant, and Snapshot, did an adequate job of controlling crabgrass in purple coneflower (Table 2). Gallery 75 DF did not control the crabgrass. All herbicides with the exception of Pennant 5G at the 3.0 lb. ai/A rate controlled spurge within the daylily treatments.

Significance to Industry: There are only a few pre-emergence herbicides labeled for herbaceous perennials. This study and others are working to insure that the diversity of weed free perennials in production can increase each year, thus meeting the demand of the buyer. This study also demonstrated that weed control is an important aspect in reducing the competition between weed and produced plant, thus allowing the produced plant to grow and reach a saleable size in a faster time frame.

Table 1. *Leucanthemum maximum* 'Snow Lady', snow lady shasta daisy seedlings response to preemergence herbicide applications (1997).

Herbicide Treatment	Rate lbs. ai/A	Foliar Phytotoxicity[Z] 15 DAT[Y]	30 DAT	60 DAT	Shoot Dry Weight (g) 60 DAT
Factor 65WG	1.5	1.5d[X]	1.2de	1.0c	11.7a
Factor 65WG	3.0	2.8bcd	2.5cd	1.0c	10.9a
Factor 65WG	6.0	2.0cd	1.0e	1.0c	12.5a
Gallery 75DF	0.5	2.8bcd	1.2de	1.8bc	10.0a
Gallery 75DF	1.0	3.2bcd	1.0e	2.0bc	9.4a
Gallery 75DF	2.0	4.2b	2.8c	2.2bc	5.2b
Pendulum 2G	2.0	7.3a	4.0b	3.7ab	9.4a
Pendulum 2G	4.0	7.7a	5.4a	4.7a	5.3b
Pendulum 2G	8.0[W]	------	------	------	------
Pennant 5G	3.0	2.8bcd	1.5cde	1.8bc	10.0a
Pennant 5G	6.0	2.5bcd	1.2de	2.0bc	11.2a
Pennant 5G	12.0	2.8bcd	2.2cde	2.8abc	10.4a
Snapshot 2.5TG	2.5	2.0cd	1.3de	1.7bc	11.1a
Snapshot 2.5TG	5.0	4.0bc	2.0cde	1.7bc	8.8a
Snapshot 2.5TG	10.0[W]	------	------	------	------
Control - Weedy	------	1.3d	1.0e	1.0c	9.6a
Control - Weeded	------	1.7d	1.0e	1.0c	12.0a

[Z]Phytotoxicity rating: 1 = healthy, 3 = slight stunting, 5 = moderate stunting, distortion on new foliage, 7 = severe stunting, distortion on new foliage, 10 = dead.
[Y]DAT = Days after herbicide application
[X]Means within column followed by the same letter are not significantly different by DMRT ($P \leq 5\%$).
[W]Data not available.

Table 2. *Digitaria sanguinalis*, crabgrass, and *Euphorbia supina*, spurge, response to preemergence herbicide applications (1997).

Herbicide Treatment	Rate lbs. ai/A	# of crabgrass[Z] 30 DAT[XW]	60 DAT	# of spurge[Y] 30 DAT	60 DAT
Factor 65WG	1.5	3.8c[V]	1.5e	0.2d	0.0b
Factor 65WG	3.0	2.8c	0.0e	0.0d	0.0b
Factor 65WG	6.0	0.5c	0.0e	0.0d	0.0b
Gallery 75DF	0.5	90.0a	24.8b	1.0d	0.2b
Gallery 75DF	1.0	62.25b	16.5bcd	0.0d	0.8b
Gallery 75DF	2.0	23.0c	7.2ed	0.0d	0.0b
Pendulum 2G	2.0	19.0c	8.0cde	3.7cd	1.7b
Pendulum 2G	4.0	8.7c	0.7e	0.0d	0.0b
Pendulum 2G	8.0	0.0c	0.0e	0.0d	0.0b
Pennant 5G	3.0	11.5c	13.0b-e	9.2bc	3.5b
Pennant 5G	6.0	2.5c	8.8cde	0.2d	1.0b
Pennant 5G	12.0	0.5c	0.0e	0.2d	1.2b
Snapshot 2.5TG	2.5	11.7c	2.3e	0.2d	0.0b
Snapshot 2.5TG	5.0	2.0c	0.7e	0.0d	0.0b
Snapshot 2.5TG	10.0	0.0c	0.0e	0.0d	1.0b
Control - Weedy	------	90.4a	95.3a	12.3b	12.0a
Control - Weeded	------	92.4a	20.0bc	19.0a	0.3b

[Z]Crabgrass numbers are an average from three containers per experimental unit.
[Y]Spurge numbers are an average from three containers per experimental unit.
[X]DAT = Days after herbicide application
[W]Weeds were counted and removed at 30 DAT with the exception of the weedy control.
[V]Means within column followed by the same letter are not significantly different by DMRT ($P \leq 5\%$).

Suppression of Liverwort Growth in Containers Using Irrigation, Mulches, Fertilizers and Herbicides
(Poster)

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Nature of Work: Liverworts (often *Marchantia spp.*) frequently infest the substrate surface of container grown ornamentals. A full mat of liverworts can restrict the movement of irrigation water and fertilizers into the substrate, and can reduce the marketability of the crop. Commercial herbicides and other products used for liverwort control may be phytotoxic, or may have limited effectiveness. Hand removal is expensive, and may damage crop roots. Use of preemergence herbicides has been suggested (Elmore et al., 1979), and are effective for some woody crops (Clemens et al., 1991). Preventative techniques are currently being studied (Svenson, 1997). Since dead liverworts on the surface of the growing substrate may be more unsightly than a live infestation, procedures and products that prevent liverwort infestions are needed. The objective of this research was to study how nursery practices influence the development of liverwort infestations in container grown nursery crops.

A series of experiments were performed to study how irrigation practices interact with other cultural procedures to influence liverwort development. The following procedures were the same for all experiments: 1) *Picea glauca* 'Albertiana Conica' or *Rhododendron* 'Jean Marie Montague' growing in four-inch (10-cm) square pots were placed in a fiberglass covered greenhouse in September or November (Aurora, OR); 2) plants were spaced [6-inches (15-cm) on center] to create four replicate blocks for high frequency irrigation (irrigated daily) or low frequency irrigation (irrigated every 3 days) in a randomized complete block design; 3) five pots were used as an experimental unit for each treatment in each block; 4) after treatments were applied, pots were inoculated with liverworts by pouring 50 ml of an inoculum slurry onto the surface of the growing substrate [slurry was made by placing 5 g (fresh weight) of liverwort thalli with visible gemmae cups (*Marchantia polymorpha*) collected from infested pots in an commercial greenhouse, 50 ml of buttermilk, and 250 mls of water in a blender and mixing for five seconds]; 5) foliage was monitored for phytotoxicity; 6) liverwort infestation was rated as the percentage of the substrate surface covered with live liverworts; 7) all data were analyzed using analysis of variance. Percentage data required square-root transformation for a valid analysis of variance. Mulches were applied at least 1/2-inch (1.3-cm) thick. Herbicides were applied according to label instructions. Other details are included with the data in each table.

Results and Discussion: High frequency irrigation increased liverwort coverage of the surface of the growing substrate (Tables 1 through 4). Increasing the amount of nitrogen from a 20N-9P-17K fertilizer increased liverwort coverage (Table 1), with nitrogen levels from 100 to 200 mg/liter (ppm) supporting the most coverage.

Hazelnut shells, oyster shells and copper-treated geotextile disc provided good suppression of liverwort growth for up to 6 weeks (table 2). Coarse sand, perlite, pumice and untreated geotextile discs suppressed liverwort growth under low frequency irrigation, but not under high frequency irrigation. Liverworts grew on the substrate surface below the untreated geotextile discs.

Surface applied microelement fertilizers and surface applied preemergent herbicides suppressed liverwort growth with low-frequency irrigation (Table 3). However, high frequency irrigation eliminated or reduced the effectiveness of these treatments.

The combination of hazelnut shells and oxadiazon provided good suppression of liverwort growth for up to 12 weeks with low frequency irrigation, and the combinations of hazelnut shells or pumice with oxadiazon provided suppression for 8 weeks with high frequency irrigation. (Table 4).

Significance to Industry: Liverwort growth appears to be optimized by high frequency irrigation and nitrogen rates between 100 and 200 mg/liter (ppm). Reducing irrigation frequency enhances the suppression of liverworts by mulches, surface-applied fertilizers or preemergent herbicides, whereas high frequency irrigation allows liverwort to avoid suppression. The best treatment for liverwort suppression in this study was a combination of low frequency irrigation, a hazelnut shell mulch, and the application of oxadiazon at label rates.

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Table 1. Influence of irrigation frequency and fertilization rate on the percentage of media surface covered with liverworts. Four-inch pots filled with a 9:1 Douglas-fir bark:peat moss substrate and potted with *Picea glauca* 'Albertiana Conica'; fertigated with 20N-9P-17K at every irrigation; leachate pH averaged 6.8; treatments were applied October 1997.

Irrigation frequency	Fertilization rate (mg/liter)	Weeks After Treatment 3	6
Percentage of substrate surface covered with liverworts (%)			
low	0	8	17
	100	17	59
	200	26	67
	400	28	51
high	0	12	34
	100	31	100
	200	34	100
	400	32	94
Significance (PR>F)[1]			
irrigation X mulch		0.05	0.01

[1] Analysis of variance indicated a significant interaction between irrigation frequency and fertilizer rate, indicating the irrigation practices influenced the response to fertilizer rate.

Table 2. Influence of irrigation frequency and surface mulch treatments on the percentage of media surface covered with liverworts. Four-inch pots filled with a 9:1 Douglas-fir bark:peat moss substrate and potted with *Picea glauca* 'Albertiana Conica'; fertilized with 20N-9P-17K at 100 ppm N every third irrigation; leachate pH averaged 7.3; treatments applied in September 1997.

Irrigation frequency	Mulch treatment	Weeks After Treatment 3	Weeks After Treatment 6
		Percentage of substrate surface covered with liverworts (%)	
low	No Mulch	16	55
	Hazelnut Shells	0	4
	Oyster Shells	0	7
	Coarse Sand	0	35
	Peat Moss	19	75
	Perlite	0	42
	Pumice	0	37
	Rockwool	17	67
	Geotextile disc	0	20
	Geotextile disc + Copper[2]	0	2
high	No Mulch	22	100
	Hazelnut Shells	0	8
	Oyster Shells	0	9
	Coarse Sand	15	78
	Peat Moss	31	100
	Perlite	17	92
	Pumice	15	85
	Rockwool	29	100
	Geotextile disc	9	32
	Geotextile disc + Copper	0	9
Significance (PR>F)[1]			
irrigation X mulch		0.01	0.01

[1] Analysis of variance indicated a significant interaction between irrigation frequency and mulch type, indicating the irrigation practices influenced the effectiveness of the mulch treatments.
[2] Geotextile material treated with SpinOutTM (Texel USA, Inc.).

Table 3. Influence of irrigation frequency, substrate surface applied fertilizers or preemergent herbicides on the percentage of media surface covered with liverworts. Four-inch pots filled with a 9:1 Douglas-fir bark:peat moss substrate and potted with *Picea glauca* 'Albertiana Conica'; fertilized with 20N-9P-17K at 100 ppm N every third irrigation; leachate pH averaged 7.2 for herbicide treatments, and 6.7 for fertilizer treatments; treatments applied in December 1997.

Irrigation frequency	Surface treatment	Weeks After Treatment 4	8
		Percentage of substrate surface covered with liverworts (%)	
low	untreated	12	34
	iron oxide (30 ppm Fe)	1	28
	copper sulfate (4 ppm Cu)	5	33
	manganese sulfate (4 ppm Mn)	3	26
	oxadiazon (4 lbs./1000 sq. ft.)	0	12
	oryzalin (3 oz./1000 sq. ft.)	0	17
high	untreated	21	92
	iron oxide (30 ppm Fe)	18	84
	copper sulfate (4 ppm Cu)	23	95
	manganese sulfate (4 ppm Mn)	16	82
	oxadiazon (4 lbs./1000 sq. ft.)	14	45
	oryzalin (3 oz./1000 sq. ft.)	17	67
Significance (PR>F)[1]			
irrigation X surface treatment		0.01	0.01

[1] Analysis of variance indicated a significant interaction between irrigation frequency and surface treatments, indicating the irrigation practices influenced the effectiveness of surface treatments.

Table 4. Influence of irrigation frequency and substrate surface-applied treatments on the percentage of media surface covered with liverworts. Four-inch pots filled with a 9:1 Douglas-fir bark:peat moss substrate and potted with *Rhododendron* 'Jean Marie Montague'; fertilized with 20N-9P-17K at 100 ppm N every third irrigation; leachate pH averaged 7.1; treatments applied December 1997.

Irrigation frequency	Surface treatment	Weeks After Treatment 4	8	12
		Percentage of substrate surface covered with liverworts (%)		
low	untreated	10	22	56
	peat moss + oxadiazon2	5	18	33
	hazelnut shells + oxadiazon	1	3	12
	hazelnut shells + ferrous sulfate[3]	2	5	17
	pumice + oxadiazon	1	3	15
	pumice + ferrous sulfate	3	7	22
high	untreated	16	100	98
	peat moss + oxadiazon	8	74	92
	hazelnut shells + oxadiazon	2	11	45
	hazelnut shells + ferrous sulfate	2	14	68
	pumice + oxadiazon	1	12	57
	pumice + ferrous sulfate	3	17	84
Significance (PR>F)[1]				
irrigation X surface treatment		0.01	0.01	0.01

[1] Analysis of variance indicated a significant interaction between irrigation frequency and surface treatments, indicating the irrigation practices influenced the effectiveness of fertilizer treatments.
[2] Oxadiazon (Chipco Ronstar G) was applied at 4 lbs. product/1000 sq. ft.
[3] Ferrous sulfate was applied at 30 ppm Fe.

Development of Herbicide Resistant 'Stella de Oro' Daylily Using Genetic Engineering
(Poster)

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Nature of Work: Daylilies (*Hemerocallis* spp.) are popular perennial plants, which are widely grown for their attractive and showy flowers. They exhibit high resistance to most pests and diseases, and are adaptable to a wide range of soils and climatic conditions. Conventional daylily breeding programs have depended upon sexual hybridization and chromosome duplication to introduce variations. Sexual incompatibility among some cultivars is restricting the timely production of new novel introductions. Advances in biotechnology have opened new avenues for the genetic improvement of daylilies. The use of genetic engineering methods for the development of 'Stella de Oro' cultivars with resistance to broad-spectrum post-emergent herbicides is significant since it is broadly used in commercial plantings.

To develop a daylily resistant to a broad-spectrum post-emergent herbicide, the following methods were used:

For Producing 'Stella de Oro' in Tissue Culture: Regenerable callus tissue was induced from ovules collected from pot grown 'Stella de Oro' plants. The callus was subcultured monthly on Murashige and Skoog's medium (MS) supplemented with 10 mg/l NAA, 2.0 mg/1 BA, 3.0-g/1 sucrose and 0.8% (w/v) agar and maintained in a growth chamber at 25°C. Suspension cell cultures were initiated from 1-week-old callus in the same medium as used above with the exception of the agar. These cultures were incubated on a gyratory shaker at 120 rpm at 25°C in the dark.

For the Preparation of Plasmid DNA: Plasmid pB2/35SAcK containing genes for AgrEvo, Frankfurt, Germany, provided PPT resistance. Plasmid pB2/35SAcK was constructed by inserting the PPTacetyltransferase (PAT) gene fused to 35Spromoter and 35Sterminator into the pUCl9 vector as an EcoR I fragment. PAT is an enzyme that detoxifies phosphinothricin (PPT), the active ingredient in the herbicide Basta, Finale, and Ignite. Plasmid DNA was amplified in the bacterium E. coli strain HB101. Plasmid DNA was isolated and purified using Wizard Minipreps Kit (Promega, Madison, WI).

For Particle gun bombardments: Plasmid DNA was delivered into plant cells using the Biolistic PDSl000/He device (BioRad, Hercules, CA). DNA was precipitated onto 1.0 (m gold particles (BIORAD, Hercules, CA) following the DuPont protocol. Suspension culture cells were collected and transferred to 95xl5mm Petri dishes containing 25 ml of MS basal medium supplemented with 10 mg/1 NAA, 2.0 mg/1 BA and 0.8% purified agar (Fisher, Atlanta, GA). The macrocarrier holder was positioned 1.5 cm (gap distance) from the rupture disk holder, and the macrocarrier was placed 6 mm from the stainless screen. Suspension culture cells were placed on the third shelf below the macrocarrier launch assembly (12cm from the stopping screen) and bombarded once for each group of cells at pressures ranging from 450 to 2200 psi under 25 in. partial vacuum.

For Screening Putative Transformants: Following bombardment, all cultures were incubated for 2 - 3 weeks at 25ºC in the dark. After incubation, the small calli were individually transferred onto a screening medium that contained the following: MS basal medium, 10 mg/l NAA, 2.0 mg/l BA, 0.8% purified agar, and 4.0 mg/l phosphinothricin (PPT)). For a better celltomedia contact, calli were separated and embedded into medium. For further screening, calli that survived this treatment were transferred onto medium containing a higher dose of PPT (5 mg/l). To increase the growth rate of calli, some were divided and cultured on a medium that containing a lower dose of PPT (1.0 mg/l).

For the Regeneration of transgenic plants: Transgenic daylily calli that have been to be transgenic by PCR/Southern analysis were cultured on MS medium that contained 2.0 mg/1 TDZ for regenerating shoots. These regenerated shoots were transferred to a hormonefree half-strength MS medium and maintained in a lighted growth chamber at 25°C for root formation.

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The use of Southern analysis on PPT-resistant calli to Confirm Transformation: Genomic DNA was isolated from PPT-resistant calli using the Plant DNA Extraction Kit (Scotlab Bioscience, Lanarkshire, Scotland). The isolated DNA was purified using the Wizard™ Minipreps DNA Purification System (Promega, Madison, WI). PCR amplification of PAT gene was performed with DNA isolated from PPT-resistant calli. The amplification was carried out using the upstream primer (5’GAGAGGAGACCAGTTGAG3') and downstream primer (5’TTGGAGGAGCTGG CAAC3') under the following conditions: 95°C for 7 min, 35 cycles of 95°C for 45 sec, 60°C for 1 min and 72C for 2 min and final extension at 72°C for 10 min. The PCR products were electrophoresed in 1.0% agarose gel and then transferred to nylon membranes. PAT gene, amplified from pB2/35SAcK and labeled with digoxigenin, was used as a probe. DNA blots were incubated in prehybridization buffer (5x SSC, 2.0% Blocking reagent for nucleic acid hybridization, 0.1% Nlauroylsarcosine, 0.02% SDS, 50% deionized Formamide) for 2 h at 45C. Then, the blots were incubated in the hybridization buffer containing 25 ng/ml DIGlabeled probe at 45°C for 16 h. Following hybridization, the signal on the nucleic acid blot was detected with calorimetric alkaline phosphatase substrates.

Additional Southern analyses were performed with DNA isolated from fresh leaves of transgenic plants that previously confirmed with PCR/ Southern analysis. The plant genomic DNA (30 µg) was digested using EcoR I or Sma I prior to analysis. After digestion, DNA was purified with Wizard DNA CleanUp System (Promega, Madison, WI). The purified DNA was electrophoresed in 1.5% (w/v) agarose gel. Following electrophoresis, capillary movement transferred the DNA overnight to a positively charged nylon membrane (Boehringer Mannheim Co, Indianapolis, IN). Hybridization was carried out using the above protocol.

For the development of a medium that effectively arrested the proliferation of non-transformed tissue, unbombarded calli were grown in MS medium that contained from 0.5 to 5.0 mg/l PPT. From this experiment, we found that a concentration of 3.0 mg/l PPT was effective for inhibiting the growth of non-transformed cells.

After 6 months of culture on a screening selective medium, 482 PPT-resistant clones were obtained. The helium pressure used for bombarding calli significantly affected the number of PPT-resistant clones. As the gas pressure was increased from 450 psi to 1350 psi, the number of PPT-resistant clones per plate increased. The maximum number of PPT-resistant clones was obtained with a pressure of 1350 psi. Pressure increases above 1350 psi resulted in a decrease of resistant clones.

To confirm the presence of the PAT gene in daylily genome, PPT-resistant clones were analyzed by PCR amplification followed by Southern blot hybridization. Positive signals were obtained from 7 of the 10 resistant clones when analyzed using the PAT coding sequences as probe, while control callus did not produce any signal.

Plant regeneration was achieved by transferring transgenic calli to a regeneration medium and incubating the cultures at 25C under a 16-h photoperiod. Shoots began to emerge after 2 months in culture. Transgenic shoots were transferred onto half-strength MS medium for root initiation. Intact transgenic plants were obtained after 6 month of culture on the rooting medium. Of the 7 transgenic lines produced, 3 lines were regenerated resulting in 30 transgenic plants.

Genomic DNA samples isolated from transgenic plants were digested with Sma I restriction enzymes. After digestion with Sma I restriction enzymes, the 804 bps and 444 bps fragments were observed as expected. This indicates that stable incorporation of the PAT gene in the daylily genome has occurred.

Significance to Industry: Using our procedure, transformation of daylily by genetic engineering is now possible. This methodology has facilitated the introductions of genes for resistance to a broad spectrum herbicide (Finale TM) into the 'Stella de Oro' daylily. This procedure can also be used for the introduction of other desirable genes such as genes for extending flower longevity. In this paper, we describe how a transgenic daylily was developed However, the behaviours of the inserted genes in this plant and their stability during plant development remain to be determined.

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Preemergent Bittercress Control on Gravel Beds

(Poster)

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Nature of Work: Gravel is commonly used on production surfaces at container plant nurseries, often overlaid on plastic or fabric. The layer of gravel provides a microsite which favors weed seed germination. Weed control on gravel production beds is necessary as weeds are secondary hosts for insects and pathogens (Hobbs et al., 1960). Weeds have also been found to be a source of nematode inoculum to container plants (Ko and Schmitt, 1997). Weeds on gravel beds also send their seeds into surrounding pots by dispersal mechanisms such as forceful dehiscence.

Bittercress (*Cardamine hirsuta* L.) is a major weed problem at container nurseries in the Southeast US. It readily establishes in gravel beds under production conditions of daily irrigation and regular fertilization. Seeds germinate year round in protected environments and each plant can produce up to 5000 seeds which are forcefully propelled for a distance of up to 42 inches (Bachman and Whitwell, 1995). Preemergence herbicides are used to control bittercress in containers, and large amounts of a broadcast applied material falls on the gravel surface. However, gravel has fewer adsorption sites for the herbicide than container substrate and control is relatively short. Research has indicated that Factor (prodiamine) and Goal (oxyfluorfen) at 2 X and 4 X normal use rates will provide long term control of bittercress in gravel. The objectives of this study were to further evaluate the efficacy of these herbicides, alone and in combination with a spreader sticker, in controlling bittercress in gravel beds, and to quantify amounts of the herbicides sorbed to the gravel layer.

Research was conducted at the Clemson/Carolina Nurseries Cooperative Research Center in Monck's Corner, SC. Prior to treatment, the site was sprayed with Finale to kill existing weeds. Plots (2m x 2m) were sprayed on Aug. 28, 1997. Treatments were Factor 65WG (2 lb ai/A; 2X rate), Goal (4 lb ai/A; 2X rate), Factor 65WG plus 10% ClearSpray (W. A. Cleary Chemical Corp), Goal plus 10% ClearSpray, ClearSpray (10%), and an untreated control. Treatments were applied with a CO^2 backpack sprayer equipped with 8006 nozzles, calibrated to deliver 100 gal/A at 40 psi. Pots containing bittercress were placed on the perimeter of the experimental plots to provide a constant supply of seed during the trial. Plots were replicated three times. Bittercress control was rated visually through 8 months after treatment on a scale of 0 to 100 with 0 = no control and 100 = complete control. Samples of gravel (from depths of 0-1 in and 1-2 in) were taken at 0, 3, 5, and 7 months after treatment. Samples were extracted in methanol and analyzed by HPLC.

Results and Discussion: Factor and Goal provided > 95% control of bittercress at 7 months after treatment (MAT) and > 88% at 8 MAT (Table 1). The addition of the speader sticker product did not enhance persistence and longevity of the herbicides. Goal + ClearSpray (CS) provided 100% control at 7 MAT but fell to 70% at 8 MAT. Factor + CS provided only 17% control at 6 MAT and <7% at 8 MAT. Factor was detected at a concentration > 20 ug/ml following application (Fig. 1). At three months after application (MAT), the concentration in the Factor +CS treatment was lower than initial concentrations. The concentration in the Factor treatment was not lower, indicating that the spreader sticker perhaps prevented bound herbicide from extraction. Factor was not detected at 7 MAT.

Goal was detected at concentrations exceeding 100 ug/ml following treatment. This declined to < 30 ug/ml at 3 MAT and < 20 ug/ml at 5 and 7 MAT. There was no difference in amounts of herbicides detected between the Goal and Goal + CS treatment.

Total amount of Factor detected was 0.73 PPM in the Factor treatment. Total amount in the Factor + CS treatment was 0.62 PPM. This difference may explain the failure of the Factor + CS treatment to control bittercress over time.

Significance to Industry: Factor and Goal were effective in controlling bittercress in gravel production beds treatments for 8 months after application. The spray additive, Clearspray, reduced bittercress control with Factor after 4 months and Goal after 8 months. The concentrations of both herbicides declined rapidly after application in the top 1 to 2 inches of the gravel. Clearspray may have reduced the availability of the herbicide to control the weeds.

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Table 1. Bittercress control at 3-8 months after treatment (MAT), 1997-98 study.

	3 MAT	4 MAT	6 MAT	7 MAT	8 MAT
	% Bittercress control				
Factor	96.7	96.7	96.7	95	91.7
Factor+CS	83.3	76.7	16.7	16.7	6.7
Goal	100	100	100	100	88.3
Goal+CS	100	100	100	100	70
Clearspray	10	10	10	10	10
Control	0	0	0	0	0
LSD P=0.05	14.9	20.5	26.4	26.7	18.7

Figure1. Concentrations of Factor (Fac) and Factor plus spreader sticker (Fac + CS) in the top two inches of a gravel bed.

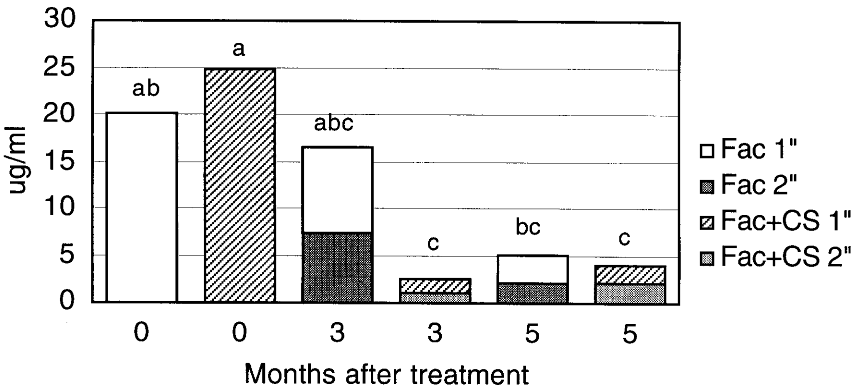
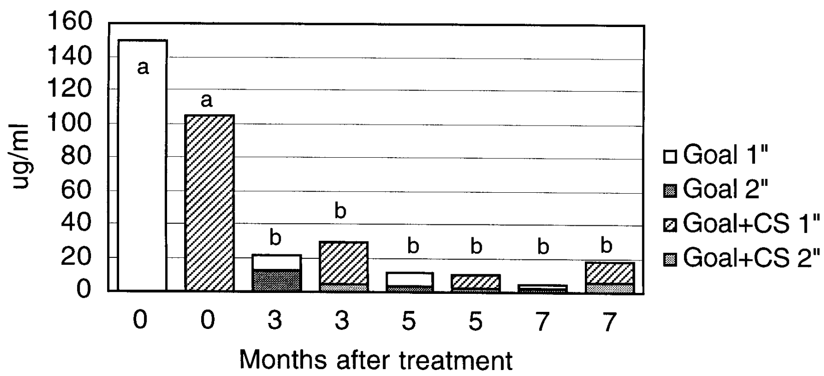


Figure 2. Concentrations of Goal and Goal plus spreader sticker (Goal + CS) in the top two inches of a gravel bed.



Weed Control in Commercial Nurseries with EC and Granule Formulations of Thiazopyr

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Nature of Work: The experimental preemergent herbicide thiazopyr was evaluated for weed control in six field grown ground covers. In addition, tolerance of these ground covers to thiazopyr was evaluated.

On May 9, 1997 at the University of Kentucky's Horticultural Research Farm, six plant species (Table 1) were transplanted into a cultivated test plot. Treatments were applied on May 21, 1997 (Table 2). Granular treatments were applied with a Gandy® drop spreader. Sprayables were applied with a CO_2 pressurized backpack sprayer using 8004 spray tips calibrated to deliver 26 GPA.

The 1998 experiment was applied to the same area that the 1997 test was performed.

Treatments were applied on May 15, 1998 (Table 3). Granulars were applied with a Scotts® drop spreader. Sprayables were applied with a CO_2 pressurized backpack sprayer using 8004 spray tips calibrated to deliver 26 GPA.

Treatments were rated visually both for weed control and injury to the ground covers. Weed control ratings were on a 0-100 scale (0=no control, 100=complete control). A complete of weeds rated in 1997 and 1998 is provided in table 4. Injury ratings were taken on a 0-100 scale (0=no injury, 100=completely dead plant). Due to limitation of publication size, only the 8 weeks after treatment (WAT) weed control ratings are presented. All data were subjected to analysis of variance. Means were separated by Duncan's New Multiple Range test with a=0.05.

Results and Discussion: Weed Control: With all treatments in 1997, annual grass control was excellent (> 90) with all herbicide treatments (Table 5). The 1.0 lb ai/A rate of both the EC and G formulations of thiazopyr (including those formulated with oxyflurofen) provided good yellow nutsedge control (78 to 91). All other treatments provided poor yellow nutsedge control. Furthermore, at a later rating date (12 WAT), thiazopyr 1.0 lb ai/A (EC formulation) was the only treatment providing any favorable degree of yellow nutsedge control (data not presented).

Fair to good control of morningglories was observed with all but the Gallery herbicide treatment. All treatments except 0.5 lb ai/A thiazopyr provided excellent control (>88) of common lambsquarters. All treatments provided fair to good control of ladysthumb, honeyvine milkweed, and pigweed. Treatments that provided 1.0 lb ai/A of thiazopyr were yielding good overall weed control ratings at 8 WAT. However, these ratings declined to fair / poor with all herbicide treatments at 12 WAT (data not presented). The overall weed control ratings were skewed low because of a johnsongrass infestation. These herbicides were not expected to control johnsongrass, however the EC formulation of thiazopyr did provide suppression of johnsongrass and this is reflected in the higher overall control ratings (data not presented).

As with the 1997 data, only the 8 WAT weed control data is presented (Table 6). As expected, the Gallery / Pennant combination provided complete yellow nutsedge control. The EC formulation of thiazopyr at 1.0 Ib ai/A by itself and in combination with dithiopyr provided fair control of yellow nutsedge, but all other treatments provided poor control (<46.7). All treatments, except Gallery / Pennant, provided fair to excellent control of Pennsylvania smartweed and morningglory species. The Gallery / Pennant and the OH2 treatments provided the best overall control of hairy galinsoga . All other treatments, except the 0.5 lb ai/A EC formulation of thiazopyr and the 0.5 lb ai/A thiazopyr in the 2.5 G. provided fair to good control of hairy galinsoga. Fair to excellent control of pigweed was attained with all treatments except the 0.5 lb ai/A EC formulation of thiazopyr. Thiazopyr and all thiazopyr combinations provide good to excellent control of honeyvine milkweed. However, honeyvine milkweed control with OH2 and Gallery / Pennant was poor. The best overall control (83.3) was provided by the tank mix of thiazopyr / dithiopyr (I .0 lb ai/ 0.5 lb ai). However, this treatment was not significantly different from any treatments that contained 1.0 lb ai/A of thiazopyr.

In 1997 and 1998, injury to english ivy, periwinkle, and winter creeper was minimal in most of the treatments. The granular combinations that contained oxyflurofen cause the most injury. At 4 WAT the highest injury to these plant species was 40 in 1997 and 16.7 in 1998. Injury to the daylillies, hostas, and ajuga was more severe in 1997 and 1998, particularly with the granular formulations containing oxyfluorfen. In 1997 and 1998, the worst injury symptoms appeared on daylillies and hostas. Injury ranged between 20 and 53 at 4 WAT. Injury to the ajuga was highly variable between 1997 and 1998. As with the other treatments, injury was most severe with the granulars containing oxyfluorfen. At 4 WAT, injury ranged from 13 to 53 in 1997 and 0 to 6.7 in 1998. However, injury declined to near acceptable levels (10 to 20) by 8 WAT in the 1997 experiment. It was apparent that the granular formulations containing thiazopyr and oxyfluorfen caused unacceptable damage to daylillies, hostas, and ajuga from l to 4 WAT. These plants were able to recover from this damage, but this injury most certainly would not be tolerated by the nursery industry. SigniElcance to Industry: Thiazopyr, a new experimental preemergent herbicide, provided good weed control of annual grasses and most broadleaves, while providing a minimum of injury to most of the ground covers. It is possible that this herbicide alone or in combination with other herbicides may be market in the near future to the nursery industry.

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Table 1. Ground cover plant species tested.

Common Name	**Scientific Name**
Daylily	*Hemerocallis species*
Hosta	*Hosta plantaginea*
Ajuga	*Ajuga repens*
English Ivy	*Hedera helix*
Common Periwinkle	*Vinca minor*
Wintercreeper	*Euonymus fortunei*

Table 2. Treatments applied in 1997

Herbicide	Formulation	Rate applied (lb ai/A)
thiazopyr	2 EC	0.5
thiazopyr	2 EC	1.0
thiazopyr	0.5 G	0.5
thiazopyr	1.0 G	1.0
thiazopyr (0.5 %) / oxyfluorfen (1.5 %)	2.0 G	1.5 (0.375 / 1.125)
thiazopyr (1.0 %) / oxyfluorfen (1.5 %)	2.5 G	2.5 (1.0 / 1.5)
thiazopyr (0.5 %) / oxyfluorfen (2.0 %)	2.5 G	2.5 (0.5 / 2.0)
thiazopyr (1.0 %) / oxyfluorfen (2.0 %)	3.0 G	3.0 (1.0 / 2.0)
Rout (oxyfluorfen (2.0 %) / oryzalin (1.0 %))	3.0 G	4.0 (2.67 / 1.33)
Gallery (isoxaben)	75 DF	1.0
Control		

Table 3. Treatments applied in 1998

Herbicide	Formulation	Rate applied (lb ai/A)
thiazopyr	2 EC	0.5
thiazopyr	2 EC	1.0
oxyfluorfen (2.0%) / thiazopyr (0.5 %)	2.5 G	2.5 (2.0 / 0.5)
oxyfluorfen (2.0%) / thiazopyr (0.5 %)	2.5 G	5.0(4.0 / 1.0)
oxyfluorfen (2.0 %) / thiazopyr (1.0 %)	3.0 G	1.5(1.0 / 0.5)
oxyfluorfen (2.0 %) / thiazopyr (1.0 %)	3.0 G	3.0 (2.0 / 1.0)
thiazopyr	2 EC	0.5
dithiopyr	1 EC	0.5
thiazopyr	2 EC	1.0
dithiopyr	1 EC	0.5
OH2 (oxyfluorfen 2.0 % +pendimethalin 1.0 %)	3.0 G	3.0 (1.0 / 2.0)
Gallery (isoxaben)	75 DF	1.0
Pennant (metolachlor)	7.8 L	4.0
Control		

Table 4. Weeds rated in 1997 and 1998.

Common Name	Scientific Name
Annual Grass species	**Main representatives:** *Seteria faberi, Echinochloa crus-galli,* and *Panicum dichotomiflorum*
Yellow nutsedge	*Cyperus esculentus*
Morningglory species	**Main representatives:** *Ipomoea lacunosa*, and *I. hederacea*
Ladysthumb	*Polygonum persicaria*
Common Lambsquarters	*Chenopodium album*
Pigweed species	**Species represented:** *Amaranthus hybridus* and *Amaranthus retroflexus*
Honeyvine milkweed	*Ampelamus albidus*
Hairy galinsoga	*Galinsoga ciliata*

Table 5. Weed control ratings eight weeks after treatment in 1997

Treatments[z]	Rate lb/ai	ANGR[y]	CYES	IPSP	POPE	CHAL	AMSP	AMAL	OVERALL
thia 2EC	0.5	100 a[x]	75 abc	88.3 a	90 ab	94.3 a	91.7 a	97.7 a	73.3 abc
thia 2EC	1.0	100 a	91.7 a	90 a	96.7 ab	100 a	99.3 a	99.3 a	92.3 a
thia 0.5 G	0.5	100 a	60 bcd	85 a	56.7 e	20 b	68.3 b	91.7 ab	46.7 d
thia 1.0 G	1.0	98.3 ab	81.7 abc	85 a	86.7 cd	91.7 a	93.3 a	90 ab	83.3 ab
thia (0.5%) + oxy (1.5%) 2.0 G	1.5	98.3 ab	53.3 cd	71.7 a	98.3 a	91 a	96 a	73.3 bc	53.3 cd
thia (1.0%) + oxy (1.5%) 2.5 G	2.5	100 a	83.3 ab	88.3 a	100 a	100 a	99.3 a	94.3 ab	86.7 a
thia (0.5%) + oxy (2.0%) 2.5 G	2.5	100 a	61.7 bc	85 a	98.3 a	94.3 a	97.7 a	91.7 ab	68.3 a-d
thia (1.0%) + oxy (2.0%) 3.0 G	3.0	100 a	78.3 abc	86.7 a	100 a	100 a	100 a	91.7 ab	79.3 ab
Rout 3.0 G	4.0	98.3 ab	55 bcd	76.7 a	100 a	100 a	100 a	61.7 c	60 bcd
Gallery 75 DF	1.0	95.0 b	31.7 d	26.7 b	81.7 d	100 a	97.7 a	90 ab	20 e
Control		0 c	0 e	0 c	0 f	0 c	0 c	0 d	0 e

[x]Means within a column followed by the same letter are not significantly different at p=0.05 as determined by Duncan's multiple range test.

[y]ANGR=annual grass, CYES=yellow nutsedge, IPSP=morningglory species, POPE=ladysthumb, CHAL=common lambsquarters, AMSP=pigweed species, AMAL=honeyvine milkweed.

[z]thia=thiazopyr, oxy=oxyfluorfen.

Table 6. Weed control ratings eight weeks after treatment, in 1998

Treatments[z]	Rate lb/ai	CYES[y]	IPSP	POPE	GASCI	AMSP	AMAL	OVERALL
thia 2EC	0.5	36.7 c[x]	80 a	73.3 a	70 bc	60 c	96.7 a	55 bcd
thia 2EC	1.0	70 ab	93.3 a	78.3 a	86.7 ab	80 c	93.3 a	75 ab
oxy (2.0%) / thia (0.5 %)	2.5	36.7 c	76.7 a	66.7 a	56.7 c	93.3 ab	80 ab	56.7 bcd
oxy (2.0%) / thia (0.5 %)	5.0	46.7 bc	85 a	83.3 a	86.7 ab	100 a	93.3 a	63.3 abc
oxy (2.0 %) / thia (1.0 %)	1.5	23.3 cd	95 a	66.7 a	76.7 abc	100 a	100 a	46.7 cd
oxy (2.0 %) / thia (1.0 %)	3.0	43.3 bc	90 a	78.3 a	86 ab	100 a	100 a	63.3 abc
thia /dithio	0.5 / 0.5	40 bc	86.7 a	90.0 a	86.7 ab	78.3 b	93.3 a	56.7 bcd
thia /dithio	1.0 / 0.5	68.3 b	86.7 a	81.7 a	88.3 ab	86.7 ab	80 ab	83.3 a
OH2 (oxy 2.0 % +pendi 1.0 %)	3.0	0 d	76.7a	86.7 a	96.7 a	100 a	56.7 b	36.7 d
Gallery / Pennant	1.0 / 4.0	100 a	40 b	36.7 b	100 a	100 a	66.7 ab	56.7 bcd
Control		0 d	0 c	0 c	0 d	0 d	0 c	0 e

[x]Means within a column followed by the same letter are not significantly different at $p=0.05$ as determined by Duncan's multiple range test

[y]CYES=yellow nutsedge, IPSP=morningglory species, POPE=ladysthumb, GASCI=hairy galinsoga, AMSP=pigweed species, AMAL=honeyvine milkweed.

[z]thia=thiazopyr, oxy=oxyfluorfen, pendi=pendimethalin