Postemergence Control of Bittercress in Container-grown Crops[1]

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Abstract

Three experiments were conducted to evaluate the effectiveness of postemergence applied herbicides for hairy bittercress (*Cardamine hirsuta* L.) control in container-grown crops. Manage (halosulfuron), Image (imazaquin), Action (fluthiacet-methyl), Resource (flumiclorac pentyl), Trimec Southern (Mecoprop + 2,4-D + dicamba), and Gallery (isoxaben) were applied to emerged bittercress in 'Variegata' and 'Big Blue' liriope. 'China Girl' holly and 'Midnight Flare' azalea were also treated with Manage, Image, Trimec Southern, and Gallery to evaluate injury. Among all experiments, Gallery provided 90 to 100% bittercress control at the labeled rate of 1.12 kg ai/ha (1.0 lb ai/A) with no injury to liriope, holly, or azalea. Among non-flowering bittercress, Manage applied at 0.035 kg ai/ha (0.031 lb ai/A) provided 90 to 100% bittercress control, with slight to moderate injury to 'Variegata' liriope; Image applied at 0.070 kg ai/ha (0.062 lb ai/A) provided 73 to 99.5% bittercress control and caused severe injury to azalea; and Trimec Southern applied at 0.31 kg ai/ha (0.28 lb ai/A) provided 50 to 100% bittercress control and caused severe injury to liriope and azalea. However, using the same rates applied to flowering bittercress Manage, Image, and Trimec Southern provided only 55, 6, and 50% bittercress control, respectively. Action and Resource did not control bittercress.

Index words: herbicide, postemergence weed control.

Herbicides used in this study: Manage (halosulfuron) methyl 5-{[(4,6-dimethoxy-2-pyrimidinyl)amino]carbonylaminosulfonyl}-3-chloro-1-methyl-1-*H*-pyrazol-4-carboxylate; Image (imazaquin) 2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1*H*-imidazol-2-y1]-3-quinolinecarboxylic acid; Action (fluthiacet-methyl) [[2-chloro-4-fluro-5-[(5,6,7,8- tetra-hydro-3-oxo-1H,3H-[1,3,4]thiadiazolo[3,4-a]pyridazin-1-ylidene)amino]phenyl]thio] acetate; Resource (flumiclorac pentyl) pentyl 2-chloro-4-fluoro-5- (3,4,5,6-tetrahydrophthalimido) phenoxyacetate; Trimec Southern (Mecoprop + 2,4-D + dicamba) [(±)-2-(4-chloro-2-methylphenoxy)propanoic acid] + [(2,4-dichlorophenoxy)acetic acid] + [3,6-dichloro-2-methoxybenzoic acid]; Gallery (isoxaben) *N*-[3-(1-ethyl-1-methylpropyl)-5-isoxazol-y1]-2,6-dimethoxybenzamide.

Weed species evaluated in this study: hairy bittercress (*Cardamine hirsuta* L.).

Landscape species evaluated in this study: 'Big Blue' liriope (*Liriope muscari* L.H. Bailey 'Big Blue'); 'Variegata' liriope (*Liriope muscari* L.H. Bailey 'Variegata'); 'China Girl' holly (*Ilex* x *meserveae* S.Y. Hu 'China Girl'); 'Midnight Flare' azalea (*Rhododendron* x 'Midnight Flare').

Significance to the Nursery Industry

Bittercress (*Cardamine hirsuta* L.) is a common weed problem in container nurseries. Previous research demonstrated that effective bittercress control can be achieved in container-grown crops using preemergence herbicides; however, none of the research addressed postemergence control. Postemergence bittercress control can be obtained with little or no crop injury by using sprayed herbicides. Gallery provides excellent bittercress control at the labeled rate [1.12 kg ai/ha (1.0 lb ai/A)] with no injury to liriope, azalea, or holly; however, control may be dependent on bittercress size and reproductive growth stage. Nonetheless, postemergence bittercress control from Gallery has great potential for use in container grown crops due to its broad crop label. Manage and Image showed promise, but had limitations due to crop injury. Manage at the labeled rate of 0.035 to 0.070 kg ai/ha (0.031 to 0.062 lb ai/A) provided good postemergence bittercress control with slight injury to liriope and azalea, and no injury to holly. Image at low rates of 0.035, 0.070, and 0.14 kg ai/ha (0.031, 0.062, and 0.125 lb ai/A) controlled bittercress in one of two studies with no significant injury to liriope or holly, but injured azalea. Trimec Southern provided good postemergence control of bittercress, but caused injury to liriope and severe injury to azalea.

Introduction

Hairy bittercress is a common weed in container nurseries (8). Though considered a winter annual, it has become a year-round problem in container-grown crops due to the favorable environment provided by daily overhead irrigation. Ryan (8) demonstrated that a successful herbicide program for season long bittercress control required frequent and repeated applications of a preemergence herbicide. Gallatino and Skroch (3) reported that bittercress control is best achieved with a weed management program consisting of herbicides in the following chemical families: diphenyl ethers, dinitroanilines, oxadiazon, and combinations of these products. However, when an effective weed management program is not maintained, bittercress can be one of the most prolific weeds to infest nursery containers (1). An infestation can occur during overwintering, when preemergence applications are made to containers that were not weeded, towards the end of the season as the chemical barrier from

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previous applications begins to deteriorate, or anytime a scheduled application is postponed or skipped. Many growers are reluctant to apply preemergence herbicides immediately after potting, fearing they will cause root inhibition. This delay in herbicide application can often lead to bittercress germination.

Since preemergence weed control programs usually fail to control all weeds, alternatives are needed for postemergence control. Several herbicides have been evaluated for postemergence grass or sedge control in container-grown crops (4, 5, 6); however, research on postemergence control of broadleaf weeds is limited. Specifically, no research has evaluated postemergence control of bittercress in container-grown crops. The objective of this study was to evaluate herbicides for postemergence control of bittercress in container-grown crops.

Materials and Methods

Three experiments were conducted to evaluate bittercress control with postemergence herbicides. Treatments were applied with a CO_2 backpack sprayer and an 8004 flat fan nozzle. Applications were made with a pressure of 1.97 kg/cm^2 (28 psi) and calibrated to deliver 187 liter/ha (20 gal/A).

Experiment 1. On June 25, 1997, 'Variegata' liriope (*Liriope muscari* L.H. Bailey 'Variegata') in 10.2 cm (4 in) diameter pots from Flowerwood Nursery in Loxley, AL, were selected with uniform populations (3 to 5 bittercress per container) of bittercress ranging from 0.5 to 2.0 cm (0.2 to 0.8 in) tall. 'Big Blue' liriope (*Liriope muscari* L.H. Bailey 'Big Blue') in similar containers from Flowerwood Nursery were also treated to evaluate injury from the herbicides. Both cultivars were single bib plants divided 6 weeks prior to treatment and potted into a pinebark medium. At the time of treatment, both cultivars had foliage approximately 7.6 cm (3 in) long. Plants were treated with the following herbicides: Manage (halosulfuron) at 0.035, 0.070, or 0.14 kg ai/ha (0.031, 0.062, or 0.125 lb ai/A) (Monsanto Co., St. Louis, MO); Image (imazaquin) at 0.28, 0.56, or 1.12 kg ai/ha (0.25, 0.5, or 1.0 lb ai/A) (American Cyanamid Co., Princeton, NJ); Action (fluthiacet-methyl) at 0.010, 0.020, or 0.040 kg ai/ha (0.009, 0.018, or 0.036 lb ai/A) (Novartis Crop Protection, Inc., Greensboro, NC); and Resource (flumichlorac pentyl) at 0.030, 0.060, or 0.121 kg ai/ha (0.027, 0.054, or 0.108 lb ai/A) (Valent USA, Walnut Creek, CA). The low and middle rates of all treatments reflect the lower and upper limits of the manufacturers' labeled rate. All treatments consisted of 10 single-plant replications in a completely randomized design (cultivars grouped separately).

Data collected included weed counts of bittercress 15 and 50 days after treatment (DAT), shoot fresh weight (SFW) and shoot dry weight (SDW) of bittercress and liriope 50 DAT, and a liriope injury rating from 1 to 5 (1 = no injury, 2 = slight injury, 3 = moderate injury, 4 = severe injury, and 5 = dead plant) 15 DAT. Weed count data were square root transformed before analyses; however, original data are presented (Table 1).

Experiment 2. On May 11, 1998, 'Big Blue' and 'Variegata' liriope were divided into single bibs and potted into 2.8 liter (trade gallon) containers with a pinebark:peat moss medium (3:1 by vol) amended per m^3 (yd^3) with 8.3 kg (14 lb) of 17N–3.1P–10K (Osmocote 17–7–12), 3.54 kg (6 lb) of dolomitic limestone, 0.9 kg (1.5 lb) of Micromax micronutrients, and 1.2 kg (2 lb) of gypsum. Containers were overseeded with 15 to 20 bittercress seed per container on May 15, 1998, and placed under 47% shade. Treatments were applied on June 15, 1998, when bittercress in 'Big Blue' were 4 to 5 cm (1.6 to 2.0 in) tall and beginning to flower, while bittercress in 'Variegata' were 2 to 3 cm (0.8 to 1.2 in) tall and not flowering.

Containers were treated with the following herbicides: Manage at 0.017, 0.035, or 0.070 kg ai/ha (0.015, 0.031, or 0.062 lb ai/A); Image at 0.035, 0.070, or 0.14 kg ai/ha (0.031, 0.062, or 0.125 lb ai/A); Trimec Southern (Mecoprop + 2,4-D + dicamba) at 0.16, 0.31, or 0.64 kg ai/ha (0.14, 0.28, or 0.57 lb ai/A) (PBI/Gordon Corp., Kansas City, MO); and Gallery (isoxaben) at 0.56, 1.12, or 2.24 kg ai/ha (0.5, 1.0, or 2.0 lb ai/A) (DowAgrosciences, Indianapolis, IN).

In an attempt to avoid injury to liriope, Manage and Image rates were lowered from those in experiment 1 so that the middle and high Manage rates reflected the manufacturer's labeled rate of 0.035 to 0.070 kg ai/ha (0.031 to 0.062 lb ai/A); respectively, Image rates were lowered so that the highest rate used was one-half the manufacturer's labeled rate of 0.28 to 0.56 kg ai/ha (0.25 to 0.50 lb ai/A). Trimec Southern rates were equal to or lower than the manufacturer's labeled rate of 0.64 to 1.88 kg ai/ha (0.57 to 1.71 lb ai/A). Low and middle rates of Gallery represent the range in labeled rates of 0.56 to 1.12 kg ai/ha (0.5 to 1.0 lb ai/A).

Gallery is labeled as a preemergence herbicide for broadleaf weed control in nursery crops, landscape plants, and established turf, and was used in this test based on a suggestion from Albert Van Hoogmoed (Overlook Nursery, Mobile, AL) that it provided postemergence bittercress control. This suggestion was supported with research by Schneegurt et al. (9), which evaluated postemergence activity of isoxaben. Their study reported that isoxaben exhibited postemergence activity with both root and foliar absorption; however, potential for postemergence use may be limited due to a low rate of absorption and poor translocation.

Treatments consisted of 10 single plant replications in a completely randomized design. Data collected included bittercress control ratings (0% = no injury, 100% = plant death) 7 and 15 DAT, bittercress SFW and SDW 20 DAT, and a liriope injury rating 7, 15, 30, and 60 DAT.

Experiment 3. Experiment 3 was similar to experiment 2 with the following exceptions. Containers [2.8 liter (trade gallon)] were filled with a pinebark:sand medium (7:1 by vol), amended per m^3 (yd^3) with 8.9 kg (15 lb) of 17N–3.1P–10K (Osmocote 17–7–12), 3.0 kg (5 lb) of dolomitic limestone, and 0.9 kg (1.5 lb) of Micromax micronutrients. Containers with no plants were over-seeded with 25 bittercress seed per container on May 15, 1998. Treatments were applied on June 10, 1998, when bittercress were between 0.5 and 2.0 cm (0.2 to 0.8 in.) tall and not flowering. In addition, six single-plant replications of established 2.8 liter (trade gallon) 'Midnight Flare' azalea (*Rhododendron* x 'Midnight Flare') and 'China Girl' holly (*Ilex* x *meserveae* S.Y. Hu 'China Girl') were treated at the same time to evaluate crop tolerance to herbicides. At the time of treatment, 'Midnight Flare' azalea were approximately 35 cm (13.8 in) tall and 25 cm (10.0 in) wide and the 'China Girl' holly were 30.5 cm (12 in) tall and 17.8 cm (7 in) wide.

Table 1. Postemergence bittercress control in container-grown 'Variegata' and 'Big Blue' liriope, experiment 1.

Herbicide	Rate (kg ai/ha)	Bittercress per container[z]		Bittercress	'Variegata'		'Big Blue'	
		15 DAT	50 DAT	Fresh weight[y] (g)	Fresh weight (g)	Injury[x]	Fresh weight (g)	Injury
Manage	0.035	0.5	0.0	0.0	4.5	2.5	11.0	1.0
Manage	0.070	0.6	0.0	0.0	5.1	2.7	10.5	1.0
Manage	0.140	0.9	0.0	0.0	4.3	2.3	10.5	1.0
Significance[w]		NS[v]	NS	NS	NS	NS	NS	NS
Image	0.280	0.7	0.0	0.0	3.8	2.5	9.9	1.0
Image	0.560	1.1	0.0	0.0	4.4	2.7	10.0	1.0
Image	1.120	1.7	0.0	0.0	3.0	2.8	10.2	1.0
Significance		L*	NS	NS	NS	NS	NS	NS
Action	0.010	3.4	5.1	1.3	6.9	1.8	13.5	1.7
Action	0.020	3.1	6.5	1.2	8.6	1.8	14.9	2.4
Action	0.040	3.6	5.4	1.2	9.9	2.2	10.7	2.4
Significance		NS	NS	NS	NS	L**	NS	L*
Resource	0.030	2.5	5.7	1.9	6.2	1.3	12.3	1.8
Resource	0.060	2.0	3.0	1.2	8.4	1.6	13.0	2.4
Resource	0.121	2.3	3.7	1.7	6.9	2.0	12.2	1.7
Significance		NS	NS	NS	NS	L**	NS	NS
Control		2.8	3.9	1.4	10.1	1.0	13.9	1.0
Contrast:[u]								
Manage vs. Control		***	***	***	***	***	**	NS
Image vs. Control		***	***	***	***	***	**	NS
Action vs. Control		NS	NS	NS	NS	***	NS	***
Resource vs. Control		NS	NS	NS	**	***	NS	***

[z]Data were square root transformed before analyses, actual counts are reported.

[y]All plants were harvested at 50 DAT for fresh and dry weight measurements.

[x]Injury was recorded at 15 DAT and rated on a scale from 1 to 5 where 1 = no injury, 2 = slight injury, 3 = moderate injury, 4 = severe injury, and 5 = plant death.

[w]Indicates if there is a rate response within a herbicide.

[v]L or NS represent linear or nonsignificant response, respectively (*, **, *** significant where $P \leq 0.05$, 0.01, 0.001, respectively).

[u]Contrast analyses were used to compare herbicides collectively to control.

Data collected to evaluate herbicide efficacy included bittercress control 7 and 15 DAT, and bittercress SFW and SDW 20 DAT. To evaluate crop tolerance to herbicides, an injury rating on holly and azalea was recorded 7, 15, 30, 60, and 80 DAT, and a growth index [(height + width + width) ÷ 3)] of holly and azalea was recorded 80 DAT.

Data from all experiments were subjected to analysis of variance. Contrast analyses were used to determine if there was a significant difference between the herbicides and the control, and regression analyses were used to determine if there was a rate response within a herbicide. Bittercress control ratings were arcsin transformed before analyses; however, original data are presented (Tables 2 and 3). Since results from SFW and SDW analyses were similar, only SFW data are presented.

Results and Discussion

Experiment 1. At 15 DAT, Manage and Image treated pots had fewer bittercress per container than the non-treated control (Table 1). At 50 DAT, all rates of Manage and Image provided 100% postemergence bittercress control. Action and Resource provided no control and were therefore not included in subsequent tests.

Though Manage and Image treatments provided excellent bittercress control, they also caused visual injury on 'Variegata' but not 'Big Blue', and reduced SFW on both cultivars. Symptoms of injury on 'Variegata' were leaf and crown necrosis. SFW of 'Variegata' and 'Big Blue' treated with Manage were reduced by 54 and 23%, respectively, when compared to non-treated controls, and SFW was reduced by 63 and 28%, respectively, when treated with Image. The amount of injury and SFW reductions were not affected by herbicide dose. These data are in contrast to those of Hurt and Vencill (5, 6), who reported no visual injury or growth reduction in liriope 4 weeks after treatment from Manage and Image applications. Hurt and Vencill (5, 6) used similar Image rates, however, Manage rates were higher in our test.

Experiment 2. At 7 DAT, bittercress control increased with increasing rate in 'Big Blue' for each herbicide (Table 2). At 15 DAT, bittercress control increased linearly with increasing Manage rates in both 'Big Blue' and 'Variegata'. The two higher Manage rates [0.035 and 0.070 kg ai/ha (0.031 and 0.062 lb ai/A)] provided 90% bittercress control in 'Variegata', while the highest level of bittercress control in 'Big Blue' was 83%. These data concur with results from

Table 2. Postemergence bittercress control in container grown liriope, experiment 2.

Herbicide	Rate kg ai/ha	Bittercress control (%)[z] 7 DAT 'Big Blue'	Bittercress control (%)[z] 7 DAT 'Variegata'	Bittercress control (%)[z] 15 DAT 'Big Blue'	Bittercress control (%)[z] 15 DAT 'Variegata'	Liriope injury[x] 7 DAT 'Big Blue'	Liriope injury[x] 7 DAT 'Variegata'	Liriope injury[x] 15 DAT 'Big Blue'	Liriope injury[x] 15 DAT 'Variegata'	Liriope injury[x] 30 DAT 'Big Blue'	Liriope injury[x] 30 DAT 'Variegata'	Liriope injury[x] 60 DAT 'Big Blue'	Liriope injury[x] 60 DAT 'Variegata'
Manage	0.017	52	15	14	66	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Manage	0.035	50	60	55	90	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Manage	0.070	79	68	83	99	1.4	1.2	1.0	1.0	1.0	1.0	1.0	1.0
Significance[w]		L***[w]	L***, Q***	L***	L**	L**	L*	NS	NS	NS	NS	NS	NS
Image	0.035	10	3	3	5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Image	0.070	25	3	6	73	1.2	1.1	1.0	1.0	1.0	1.0	1.0	1.0
Image	0.140	75	58	43	95	1.1	1.2	1.0	1.0	1.5	1.0	1.0	1.0
Significance		L***	L***, Q**	L***	L***, Q***	NS	NS	NS	NS	NS	NS	NS	NS
Trimec Southern	0.16	73	78	55	58	1.2	1.3	1.2	1.0	1.3	1.0	1.4	1.0
Trimec Southern	0.31	82	81	50	77	1.4	1.4	1.1	1.0	1.3	1.0	1.4	1.0
Trimec Southern	0.64	96	89	72	97	1.8	1.5	1.7	1.0	2.0	1.0	1.8	1.0
Significance		L***	L**	NS	L***	L**	NS	NS	NS	NS	NS	NS	NS
Gallery	0.56	77	24	29	78	1.2	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Gallery	1.12	88	78	90	98	1.1	1.1	1.0	1.0	1.0	1.0	1.0	1.0
Gallery	2.24	91	80	98	100	1.2	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Significance		L*	L***, Q***	L***, Q***	L***, Q**	NS	NS	NS	NS	NS	NS	NS	NS
Control		0	0	0	0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Contrast:[v]													
Manage vs. Control		***	***	***	***	NS	NS	NS	NS	NS	NS	NS	NS
Image vs. Control		***	***	**	***	NS	NS	NS	NS	NS	NS	NS	NS
Trimec Southern vs. Control		***	***	***	***	***	***	***	NS	***	NS	***	NS
Gallery vs. Control		***	***	***	***	NS	NS	NS	NS	NS	NS	NS	NS

[z]Where 0% = no injury and 100% = plant death; data were arcsin transformed before analyses, actual percentages are reported.

[y]Shoot fresh weight recorded 15 DAT (July 1, 1998).

[x]Scale from 1 to 5 where 1 = no injury, 2 = slight injury, 3 = moderate injury, 4 = severe injury, and 5 = plant death.

[w]L or NS represent linear or nonsignificant responses (*, **, *** significant where $P \leq 0.05, 0.01, 0.001$, respectively).

[v]Contrast analyses were used to compare whole herbicides to control.

Table 3. Postemergence bittercress control and injury to container grown azalea, experiment 3.

Herbicide	Rate kg ai/ha	Bittercress control[z] (%)		Bittercress SFW[y] (g)	Azalea injury[x]					Azalea GI[w] (cm)
		7 DAT[v]	15 DAT	20 DAT	7 DAT	15 DAT	30 DAT	60 DAT	80 DAT	
Manage	0.017	9	89	1.7	1.0	1.0	1.0	1.0	1.0	46.2
Manage	0.035	7	89	0.5	1.0	1.0	1.0	1.0	1.0	42.6
Manage	0.070	48	99	0.1	1.0	1.2	1.0	1.2	1.5	43.6
Significance		L***[u]	NS	NS	NS	NS	NS	NS	NS	NS
Image	0.035	56	93	0.2	1.0	2.0	1.2	2.3	1.8	45.1
Image	0.070	61	100	0.0	1.0	2.0	2.2	3.0	2.7	38.7
Image	0.140	82	100	0.0	1.0	2.0	2.7	3.2	3.3	36.2
Significance		L*	NS	NS	NS	NS	L***	L*	L**	L**
Trimec Southern	0.16	90	100	0.0	1.5	1.8	3.2	3.0	3.0	34.1
Trimec Southern	0.31	100	100	0.0	1.7	2.2	3.2	3.3	3.3	34.3
Trimec Southern	0.64	100	100	0.0	2.0	2.7	4.3	4.3	4.2	25.2
Significance		L**, Q*	NS	NS	NS	L*	L**	L**	L*	NS
Gallery	0.56	82	94	0.1	1.0	1.0	1.0	1.0	1.0	46.4
Gallery	1.12	85	100	0.0	1.0	1.0	1.0	1.0	1.0	47.0
Gallery	2.24	84	100	0.0	1.0	1.0	1.0	1.0	1.0	38.6
Significance		NS	L*, Q*	NS	NS	NS	NS	NS	NS	NS
Control		0	0	3.3	1.0	1.0	1.0	1.0	1.0	43.9
Contrast:[t]										
Manage vs. Control		**	***	**	NS	NS	NS	NS	NS	NS
Image vs. Control		***	***	***	NS	***	***	***	***	NS
Trimec Southern vs. Control		***	***	***	***	***	***	***	***	***
Gallery vs. Control		***	***	***	NS	NS	NS	NS	NS	NS

[z]Where 0% = no injury and 100% = plant death; data were arcsin transformed before analyses, actual percentages are reported.

[y]Shoot fresh weight.

[x]Scale from 1 to 5 where 1 = no injury, 2 = slight injury, 3 = moderate injury, 4 = severe injury, and 5 = plant death.

[w]Growth index = (height + width + width) / 3.

[v]Days after treatment.

[u]L, Q, or NS represent linear, quadratic, or nonsignificant resoponse, respectively (*, **, *** significant where P ≤ 0.05, 0.01, 0.001, respectively).

[t]Contrast analyses were used to compare whole herbicides to control.

experiment 1 in that Manage provided excellent bittercress control; however, bittercress control with the reduced rate of Manage was not acceptable.

In experiment 1, Image provided complete bittercress control; however, in experiment 2 bittercress control was 75%, with the exception of 0.14 kg ai/ha (0.125 lb ai/A) applied in 'Variegata' which provided 95% control. SFW was reduced by 75% ('Big Blue') and 96% ('Variegata') when comparing the lowest Image rate [0.035 kg ai/ha (0.031 lb ai/A)] to the highest rate [0.14 kg ai/ha (0.125 lb ai/A)] used in experiment 2.

With Image treatments, bittercress control in 'Big Blue' increased linearly with increasing rates while control in 'Variegata' increased linearly and quadratically. Bittercress SFW decreased linearly with increasing Image rate in 'Big Blue' and decreased linearly and quadratically with increasing Image rate in 'Variegata'.

At 15 DAT, Trimec Southern gave only fair control of bittercress in 'Big Blue' at the highest rate. Control increased in 'Variegata' with increasing rates of Trimec Southern. Bittercress SFW decreased linearly with increasing Trimec Southern rates in both cultivars.

At 15 DAT, the two higher Gallery rates [1.12 and 2.24 kg ai/ha (1.0 and 2.0 lb ai/A)] provided 90 and 98% bittercress control, respectively, in 'Big Blue', and 98 and 100% control, respectively, in 'Variegata' (Table 2). Bittercress SFW responded similarly to bittercress control, and is therefore not presented.

While not compared statistically, bittercress control was greater in containers with 'Variegata' where bittercress were smaller [2 to 3 cm (0.8 to 1.2 in)] and non-flowering when treated, compared to bittercress among 'Big Blue' where bittercress were larger [4 to 5 cm (1.6 to 2.0 in)] and flowering. For example, at 15 DAT across treatments, bittercress control was 50% in 'Big Blue' compared to 78% in 'Variegata'. Also, the authors observed that control of more mature, flowering bittercress in 'Big Blue' declined from 7 DAT to 15 DAT with the lowest rate of all herbicides, suggesting that bittercress were recovering from those herbicide treatments. However, with non-flowering bittercress in

'Variegata', control at the same rates appeared to increase from 7 DAT to 15 DAT, with the exception of Trimec Southern. This observation may explain why growers have indicated varying degrees of success with Gallery for postemergence bittercress control.

At 7 DAT, slight injury was observed in Manage and Trimec Southern treatments. A linear increase in injury was observed on both cultivars of liriope with increasing rates of Manage; however, by 15 DAT plants had recovered from that injury. No injury was observed on either cultivar from Image or Gallery treatments. At 7 DAT, Trimec Southern caused significant injury to 'Big Blue' and 'Variegata'. By 15 DAT, no injury symptoms were detectable on 'Variegata'; however, injury on 'Big Blue' continued through 60 DAT. Injury was characterized by necrosis at the leaf tip and twisting of the foliage and inflorescence. These data demonstrate that reducing the Manage and Image rates reduced injury compared to higher rates applied in experiment 1.

Experiment 3. By 15 DAT, all herbicides provided about 90% or greater bittercress control (Table 3). These data concur with experiment 2 in that when these postemergence herbicides were applied to small, non-flowering bittercress, control was excellent.

Gallery caused no visible injury or growth reduction to azalea. These results concur with those found by Neal and Senesac (7) on the tolerance of woody landscape plants to Gallery. Manage at 0.070 kg ai/ha (0.062 lb ai/A) caused slight injury to 'Midnight Flare' azalea, characterized by stunting of the new foliage. This injury was not observed 7 DAT; however, injury increased gradually with time. These data concur with results from Derr et al. (2). 'Midnight Flare' azalea treated with Image showed no signs of injury 7 DAT; however, all rates provided moderate injury 15, 30, 60, and 80 DAT, characterized by chlorosis, stunting, and rosetting of the new foliage. These results concur with those observed by Hurt and Vencill (5). Moderate to severe injury of 'Midnight Flare' occurred from all Trimec Southern rates. Injury from Trimec Southern was characterized by discoloration of the foliage, twisting of the stems, premature leaf drop, and in some cases plant death. Contrast analyses of growth index data showed that Trimec Southern was the only herbicide to reduce azalea growth. 'China girl' holly showed no visual injury or growth reduction from any herbicide treatment (data not shown).

In summary, these results show that excellent postemergence bittercress control can be obtained in container-grown landscape crops. Gallery, a preemergence applied herbicide with a broad label for nursery and landscape crops, provided 90 to 100% bittercress control when applied to non-flowering bittercress at the label rate of 1.12 kg ai/ha (1.0 lb ai/A). Manage and Image provided excellent control; however, slight injury occurred on landscape crops at rates necessary for bittercress control. Manage or Image are not registered for use in container-grown nursery crops.

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