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# Effect of Bittercress Size and Gallery Rate on Postemergence Bittercress Control[1]

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## Abstract

Two experiments were conducted to evaluate the effect of Gallery (isoxaben) rate and hairy bittercress (*Cardamine hirsuta* L.) size on postemergence bittercress control and subsequent preemergence bittercress control. Treatments included Gallery applied at 0.56, 1.12, and 2.24 kg ai/ha (0.5, 1.0, and 2.0 lb ai/A), Image (imazaquin) applied at 0.070 kg ai/ha (0.06 lb ai/A), and a non-treated control. Treatments were applied to bittercress characterized as either small, intermediate, or large. A Gallery rate × bittercress size interaction for postemergence bittercress control was observed in experiment 1. At 28 days after treatment (DAT), the lowest Gallery rate [0.56 kg ai/ha (0.5 lb ai/A)] provided less than 40% control across all bittercress sizes; the middle Gallery rate provided 90% bittercress control of small and intermediate size bittercress but only 43% control of large bittercress, and the high Gallery rate provided 86 to 91% bittercress control across all bittercress sizes. At 28 DAT, control increased linearly with increasing Gallery rate in large bittercress, and linearly and quadratically in small and intermediate sized bittercress, respectively. There were no interactions in experiment 2; however, Gallery rate and bittercress size main effects were significant. At 14 DAT, bittercress control increased linearly with increasing Gallery rate. Across all rates, Gallery provided 92% control of small bittercress, 71% control of intermediate bittercress, and only 48% control of large bittercress. In both experiments, Image provided 92 to 100% bittercress control of small and intermediate bittercress, and 83 to 96% control of large bittercress. Gallery provided better subsequent preemergence bittercress control with fewer bittercress per container at 60 DAT when applied to small or intermediate sized bittercress than when applied to large bittercress (experiment 2). 'Natchez' crapemyrtle was not affected by any treatment.

**Index words:** herbicide, postemergence weed control, preemergence weed control, container-grown crops.

**Herbicides used in this study:** Image (imazaquin) 2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1*H*-imidazol-2-y1]-3-quinoline carboxylic acid; Gallery (isoxaben) *N*-[3-(1-ethyl-1-methylpropyl)-5-isoxazoly1]-2,6-dimethoxybenzamide.

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

### Significance to the Nursery Industry

A limited number of herbicides are available for selective postemergence broadleaf weed control in container-grown crops, although several postemergence herbicides are available for agronomic and turf crops. Previous research by the authors showed that Gallery (isoxaben, Dow Agrosciences, Indianapolis, IN) provided excellent hairy bittercress (*Cardamine hirsuta* L.) control with no injury to liriope, azalea, or holly (1). However, control from Gallery varied and may have been dependent on bittercress size or reproductive stage. The following data show that bittercress size and Gallery rate influenced the level of postemergence bittercress control. Gallery applied at 1.12 kg ai/ha (1.0 lb ai/A) provided excellent control of small, nonflowering bittercress and poor control of large flowering bittercress. In addition, subsequent preemergence bittercress control was more effective when Gallery was applied to small, nonflowering bittercress than when applied to large, flowering bittercress.

### Introduction

Hairy bittercress is a common weed problem in container nurseries (10). Though considered a winter annual, it has become a season-long problem in container-grown crops due to the favorable environment provided by daily overhead irrigation. Gallatino and Skroch (5) reported that bittercress control is best achieved with a weed management program consisting of preemergence herbicides in the following chemical families: diphenyl ethers, dinitroanilines, oxadiazon, or combinations of these products. When an effective weed management program is not maintained, bittercress can be one of the most prolific weeds to infest nursery containers (2). Identification of a herbicide for postemergence bittercress control in container-grown crops would offer nurserymen additional options for weed management. Previous research demonstrated that Gallery can provide excellent postemergence bittercress control; however, results appeared to vary with size and growth stage of bittercress (1). These data concur with grower observations that postemergence bittercress control with Gallery is variable.

Among other weed species, decreasing postemergence weed control has been reported with increased weed size. Trammell et al. (14) demonstrated that postemergence control of velvetleaf (*Abutilon theophrasti* Medic) and cocklebur (*Xanthium pensylvanicum* Wallr.) with Cobra (lactofen) was good-to-excellent with plants up to 20 cm (8 in) tall, but control declined as weeds grew above 20 cm (8 in) tall. Similarly, Snipes and Lanham (12) demonstrated that postemergence control of johnsongrass (*Sorghum halepense* (L.) Pers.), barnyardgrass (*Echinochloa crus-galli* (L.) Beauvois), and southwestern cupgrass (*Eriochloa gracilis* (Fourn.) A.S. Hitchc.) with clethodim, quizalofop, fluazifop-P, and sethoxydim declined when herbicides were applied to weeds taller than 15.2 cm (6 in).

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While excellent postemergence bittercress control has been demonstrated under certain conditions with Gallery, control has not been consistent under field conditions. Determining if postemergence control from Gallery is influenced by bittercress size would provide useful information to nursery growers in developing a weed management strategy for postemergence bittercress control in container-grown crops. Also, subsequent preemergence bittercress control after application for postemergence bittercress control would benefit growers by providing residual control and a more flexible weed management schedule after treatment. Therefore, the objectives of this research were to determine if postemergence bittercress control with Gallery is affected by bittercress size and if Gallery provides subsequent preemergence bittercress control.

## Materials and Methods

In both experiments, treatments were applied with a $CO_2$ backpack sprayer calibrated to deliver 187 liter/ha (20 gal/A), with an 8004 flat fan nozzle. Applications were made with a pressure of 2.0 kg/cm$^2$ (28 psi). Both experiments were completely randomized designs (CRD) with treatments in a 3 × 3 augmented factorial arrangement.

*Experiment 1*. On September 14, 1998, 2.8 liter (trade gallon) containers were filled with a pine bark:sand medium (6:1 by vol), amended per m$^3$ (yd$^3$) with 8.9 kg (15 lb) of 17N–3.1P–10K (Osmocote 17–7–12, Scotts Co., Marysville, OH), 3.0 kg (5 lb) of dolomitic limestone, and 0.9 kg (1.5 lb) of Micromax (Scotts Co.) micronutrients. Three separate groups of 50 containers with no plants were overseeded with 20 bittercress seed each at two-week intervals and placed under 47% shade with overhead irrigation. On November 11, 1998, containers were divided into 3 groups containing either small, intermediate, or large bittercress. Small bittercress were 0.5 to 3 cm (0.2 to 1.2 in) tall and not flowering, intermediate bittercress were 4 to 6 cm (1.6 to 2.4 in) tall with some beginning to flower, and large bittercress were 10 to 15 cm (3.9 to 5.9 in) tall and flowering. Selective weeding was done prior to treatment to achieve the desired bittercress size within a container and to remove other weed species. Each container contained 3 to 5 bittercress plants. Containers were treated on November 11, 1998, irrigation was withheld for 20 hours, and then the daily irrigation schedule resumed. Treatments included Gallery applied at 0.56, 1.12, or 2.24 kg ai/ha (0.5, 1.0, or 2.0 lb ai/A), Image (imazaquin) (American Cyanamid Co., Princeton, NJ) applied at 0.07 kg ai/ha (0.06 lb ai/A), and a non-treated control. Low and middle Gallery rates represent the labeled rate. Image was used at a rate shown to be effective in previous work (1). Due to availability of bittercress infested containers, there were 8 single-container replications for treatments with small and large bittercress, and 5 single-container replications for treatments with intermediate size bittercress.

To evaluate postemergence bittercress control, bittercress control ratings (0% = no injury, 100% = plant death) were made 7, 14, 21, and 28 days after treatment (DAT); and bittercress shoot fresh weight and shoot dry weight (SFW and SDW) were determined 28 DAT. Bittercress injury ratings were arcsin transformed before analyses; however, original data are reported (Table 1).

*Experiment 2*. Experiment 2 was conducted similarly to experiment 1 with the following exceptions. On January 19, 1999, 10.2 cm (4 in) diameter pots of 'Natchez' crapemyrtle (*Lagerstroemia indica* L. 'Natchez') were potted into 3.8 liter (one gal) containers with the same medium used in experiment 1. Plants were placed in full sun and allowed to become infested with natural populations of bittercress. On April 7, 1999, plants were divided into 3 groups according to bittercress size (characterized as small, intermediate, and large) and treated. Small bittercress were 1 to 5 cm (0.4 to 2.0 in) tall and not flowering, intermediate bittercress were 10 to 12 cm (4.0 to 4.8 in) tall and flowering, and large bittercress were 20 to 22 cm (8.0 to 8.7 in) tall, flowering and bearing seed. At the time of herbicide application,

**Table 1. Effect of Gallery rate and bittercress size on postmergence bittercress control, experiment 1.**

| | | Bittercress shoot injury (%)[z] | | | | | |
|---|---|---|---|---|---|---|---|
| | | | Image | Gallery | | | |
| | Bittercress size | Non-treated control | 0.06[y] | 0.56 | 1.12 | 2.24 | Significance |
| 14 DAT[x] | small (0.5 to 3 cm) | 0a | 75a | 23b[w] | 53a | 55a | L*, Q*[v] |
| | intermediate (4 to 6 cm) | 0a | 93a | 40a | 60a | 46a | NS |
| | large (10 to 15 cm) | 0a | 75a | 19b | 24b | 40a | L** |
| 21 DAT | small (0.5 to 3 cm) | 0a | 99a | 30b | 68a | 82a | L*** |
| | intermediate (4 to 6 cm) | 0a | 98a | 52a | 74a | 78a | NS |
| | large (10 to 15 cm) | 0a | 88b | 20b | 40b | 69a | L*** |
| 28 DAT | small (0.5 to 3 cm) | 0a | 100a | 35a | 90a | 91a | L***, Q*** |
| | intermediate (4 to 6 cm) | 0a | 100a | 40a | 90a | 86a | L*, Q** |
| | large (10 to 15 cm) | 0a | 96b | 16b | 43b | 86a | L*** |

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

[y]Herbicide rates in kg ai/ha.

[x]Days after treatment.

[w]Similar letters were not significantly different (LSD: P = 0.05), means separation were among size groups within a given date. NS represents no significance.

[v]NS, L, and Q represent not significant, linear, and quadratic responses, respectively, with respect to Gallery rate within a size group and given date (*, **, *** significant where P ≤ 0.05, 0.01, 0.001, respectively).

'Natchez' crapemyrtle were 35 to 45 cm (14 to 18 in) tall and beginning to leaf out. Treatments were replicated with 8 single containers.

Data collected for postemergence bittercress control included bittercress control ratings 7 and 14 DAT, and bittercress SFW and SDW 21 DAT. Subsequent preemergence bittercress control was evaluated by counting the number of bittercress per container 60 DAT. Injury to crapemyrtle was evaluated 7, 14, 21, 30, and 60 DAT on a scale of 1 to 5 (1 = no injury, 2 = slight injury, 3 = moderate injury, 4 = severe injury, and 5 = plant death).

## Results and Discussion

*Experiment 1*. Significant Gallery rate x bittercress size interactions occurred with bittercress control ratings 14, 21, and 28 DAT (Table 1). At 14 and 21 DAT, the low Gallery rate [0.56 kg ai/ha (0.5 lb ai/A)] provided greater control of intermediate size bittercress compared to small and large bittercress. On all dates, when Gallery was applied at 1.12 kg ai/ha (1.0 lb ai/A) greater control was observed with either small or intermediate size bittercress than with large bittercress. There were no differences in control due to bittercress size when Gallery was applied at 2.24 kg ai/ha (2.0 lb ai/A). At 28 DAT, control of small and intermediate bittercress increased quadratically with increasing Gallery rate, and linearly on large bittercress. Bittercress control was less than 52% with the low Gallery rate regardless of bittercress size. Gallery applied at 1.12 kg ai/ha (1.0 lb ai/A) provided 90% control of small and intermediate bittercress, but only 43% control of large bittercress. The high Gallery rate provided 86% or greater control across all bittercress sizes. At 21 and 28 DAT Image provided greater control of small and intermediate bittercress than of large bittercress.

Gallery rate had no effect on bittercress SFW (Table 2). Bittercress that were small or intermediate in size at the time of treatment had similar SFW which were 90% smaller than similar sized non-treated controls, while bittercress that were large at the time of treatment had SFW which were only 59% smaller than non-treated controls. Bittercress SDW followed a trend similar to SFW.

The authors observed that Image controlled bittercress more rapidly than Gallery. Bittercress treated with Image dessicated by 15 DAT, while bittercress treated with Gallery gradually declined from 15 to 28 DAT. At 15 DAT, bittercress control from Image ranged from 75 to 93%, while control from Gallery was 60% or less (Table 1). By 21 DAT, bittercress control from Image was 88% or greater while control from Gallery improved, but still varied from 20 to 82%. Bittercress treated with Image had SFW 87% smaller than bittercress treated with Gallery (Table 2), partly as a result of rapid foliar dessication.

*Experiment 2*. Similar to experiment 1, bittercress control was influenced by bittercress size and Gallery rate; however, there were no significant interactions between main effects. At 14 DAT, bittercress control increased linearly with increasing Gallery rate (Table 3). Bittercress size at the time of treatment influenced the degree of control from Gallery, with the greatest control occurring among smaller, non-flowering bittercress (7 and 14 DAT). At 14 DAT, Gallery provided 92% control of small bittercress, 71% control of intermediate bittercress, and 48% control of large bittercress. Results from experiments 1 and 2 concur with other research concerning the effect of weed size on postemergence herbicide efficacy, in that with other postemergence herbicides weed control of small weeds was most effective, and control decreased as weed size increased (3, 4, 14).

**Table 2. Effect of herbicide and bittercress size on shoot fresh weight and shoot dry weight, experiment 1.**

| Herbicide | Rate (kg ai/ha) | Bittercress | |
|---|---|---|---|
| | | Fresh wt (g) | Dry wt (g) |
| Gallery | 0.56 | 10.3 | 1.5 |
| Gallery | 1.12 | 10.0 | 1.5 |
| Gallery | 2.24 | 6.6 | 1.0 |
| | | NS | NS |
| | **Bittercress size** | | |
| Gallery | small (0.5 to 3 cm) | 1.4b[z] | 0.3b |
| | intermediate (4 to 6 cm) | 5.8b | 0.9b |
| | large (10 to 15 cm) | 18.4a | 2.7a |
| Image | small (0.5 to 3 cm) | 0.0b | 0.0b |
| | intermediate (4 to 6 cm) | 0.0b | 0.0b |
| | large (10 to 15 cm) | 3.2a | 0.7a |
| Control | small (0.5 to 3 cm) | 13.5b | 1.2b |
| | intermediate (4 to 6 cm) | 58.5a | 5.4a |
| | large (10 to 15 cm) | 45.2a | 5.2a |
| Contrast[y] | | | |
| Gallery vs Image | | *** (9.0 vs 1.2) | *** (1.3 vs 0.3) |
| Gallery vs Control | | *** (9.0 vs 36.3) | *** (1.3 vs 3.7) |

[z]No significant response to Gallery rate.

[y]Similar letters are not significantly different (LSD: P = 0.05), means separation are among size groups within a herbicide treatment.

[x]Contrast analysis was used to compare Gallery, Image, and controls.

*** Significant where P ≤ 0.001.

Bittercress SFW and SDW were not affected by Gallery rate. However, bittercress size at the time of Gallery application resulted in SFW and SDW trends similar to those with bittercress control; large bittercress were more difficult to control. With small bittercress, SFW and SDW were negligible, while among large bittercress SFW and SDW were 48.1 and 7.7 g, respectively. Bittercress that were large when treated had SFW only 12% smaller than similar size non-treated controls. These data concur with results in experiment 1 in that large bittercress were more difficult to control.

Subsequent preemergence bittercress control was not affected by Gallery rate, but was influenced by bittercress size at the time of treatment. There were 3 times more bittercress in containers with large bittercress at the time of treatment than when small or intermediate size bittercress were present at the time of treatment; however, subsequent preemergence control was unacceptable in all treatments. This increased population was probably due to greater weed pressure from seed dispersal of seeding plants. Previous research has demonstrated that less effective preemergence weed control occurs under heavy weed pressure (7). Also, greater interception of Gallery by large bittercress plants compared to smaller bittercress plants could have reduced preemergence control.

**Table 3. Effect of Gallery rate and bittercress size on postemergence bittercress control and subsequent preemergence bittercress control, experiment 2.**

| Herbicide | Rate (kg ai/ha) | Bittercress shoot injury (%)[z] | | Bittercress | | Preemergence control (Bittercress per container) |
|---|---|---|---|---|---|---|
| | | 7 DAT[y] | 14 DAT | Fresh wt (g) | Dry wt (g) | 60 DAT |
| Gallery | 0.56 | 56 | 63 | 23.3 | 3.5 | 5.6 |
| Gallery | 1.12 | 61 | 72 | 16.6 | 2.9 | 4.6 |
| Gallery | 2.24 | 60 | 75 | 18.7 | 3.0 | 9.5 |
| Significance | | NS[x] | L* | NS | NS | NS |
| | **Bittercress size** | | | | | |
| Gallery | small (1 to 5 cm) | 84a[w] | 92a | 0.3c | 0.0c | 4.0b |
| | intermediate (10 to 12 cm) | 65b | 71b | 10.1b | 1.6b | 3.9b |
| | large (20 to 22 cm) | 29c | 48c | 48.1a | 7.7a | 11.7a |
| Image | small (1 to 5 cm) | 90a | 99a | 0.0c | 0.0c | 11.0a |
| | intermediate (10 to 12 cm) | 66b | 92b | 7.3b | 1.3b | 6.6a |
| | large (20 to 22 cm) | 51c | 83c | 25.1a | 4.8a | 8.4a |
| Control | small (1 to 5 cm) | 0a | 0a | 16.7c | 2.4c | 8.9a |
| | intermediate (10 to 12 cm) | 0a | 0a | 33.8b | 5.4b | 23.5a |
| | large (20 to 22 cm) | 0a | 0a | 54.9a | 9.3a | 21.4a |
| Contrast[v] | | | | | | |
| Gallery vs Image | | NS (59.1 vs 68.9) | *** (70.2 vs 91.5) | NS (19.5 vs 10.8) | NS (3.1 vs 2.1) | NS (6.6 vs 8.7) |
| Gallery vs Control | | *** (59.1 vs 0) | *** (70.2 vs 0) | ** (19.5 vs 35.1) | ** (3.1 vs 5.7) | *** (6.6 vs 17.9) |

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

[y]Days after treatment.

[x]Similar letters were not significantly different (LSD: P = 0.05), means separation were among size groups within a herbicide treatment and given date. NS represents no significance.

[w]No significant differences between means.

[v]Contrast analysis was used to compare Gallery, Image, and controls.

*, **, *** Significant where P ≤ 0.05, 0.01, 0.001, respectively.

There were no signs of injury or growth reduction in 'Natchez' crapemyrtle from any treatment (data not shown).

In summary, Gallery provided excellent postemergence bittercress control and better subsequent preemergence bittercress control when applied to small [less than 5 cm (2 in)] non-flowering bittercress. As bittercress grew and matured, post and preemergence control became more difficult. Schneegurt et al. (11) reported a low rate of absorption and poor translocation with foliar applied isoxaben. Percent coverage of the plant surface should have been higher with smaller bittercress than larger bittercress because more of the foliage would have been exposed to the fine layer of spray provided from applications calibrated to deliver 187 liter/ha (20 gal/A). Increased percent coverage could have result in a higher proportion of the plant absorbing isoxaben, and thus better postemergence control. Also, because more plant metabolites move to flowering structures as flowering is initiated, control may have been increased by treating nonflowering bittercress.

Many plant species have tolerance to Gallery (6, 8, 9, 13), making it ideal for postemergence control of bittercress in container-grown crops. This provides nurserymen with another weed management tool when preemergence herbicide programs fail to provide complete bittercress control.

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