# Preemergence and Early Postemergence Control of Selected Container Nursery Weeds with BroadStar, OH2, and Snapshot TG[1]

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## Abstract

Preemergence and early postemergence control of three common nursery weeds with BroadStar (flumioxazin), OH2 (oxyfluorfen + pendimethalin), and Snapshot TG (isoxaben + trifluralin) was compared in greenhouse and outdoor experiments. Hairy bittercress (*Cardamine hirsuta*), spotted spurge (*Chamaesyce maculata*), and common groundsel (*Senecio vulgaris*) were container-grown in the absence of ornamental crops and each herbicide was applied preemergence (labeled application) or postemergence to plants either at the cotyledon to one-leaf stage or at the two- to four-leaf stage. Each of the herbicides controlled hairy bittercress and spotted spurge preemergence and when applied to plants at the cotyledon to one-leaf stage. The herbicides were less effective on hairy bittercress and spotted spurge at the two- to four-leaf stage, yet control was 60 to 89%. Common groundsel was controlled preemergence by each herbicide; however, only BroadStar and OH2 controlled common groundsel ≥ 81% when applied at the cotyledon to one-leaf stage. No postemergence treatment controlled common groundsel when applied at the two- to four-leaf stage.

**Index words:** container nursery crops; growth stage; herbicide; weed management.

**Species used in this study:** hairy bittercress (*Cardamine hirsuta* L.); spotted spurge (*Chamaesyce maculata* (L.) Small); common groundsel (*Senecio vulgaris* L.).

**Herbicides used in this study:** BroadStar (flumioxazin), 2-[7-fluoro-3,4-dihydro-3-oxo-4-(2-propynyl)-2*H*-1,4-benzoxazin-6-yl]-4,5,6,7-tetrahydro-1*H* -isoindole-1,3(2*H*)-dione; OH2, (oxyfluorfen), 2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluoromethyl)benzene, plus (pendimethalin), *N*-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine; Snapshot TG (isoxaben), *N*-[3-(1-ethyl-1-methylpropyl)-5-isoxazolyl]-2,6-dimethoxybenzamide, plus (trifluralin), 2,6-dinitro-*N*,*N*-dipropyl-4-(trifluoromethyl)benzenamine.

### Significance to the Nursery Industry

During container production of nursery crops, it is difficult to remove all emerged weeds prior to preemergence herbicide applications, or to apply preemergence herbicides before new weed seeds have germinated following a hand weeding. Therefore, preemergence and early-postemergence control of common broadleaf weeds with three preemergence herbicides, BroadStar, OH2, and Snapshot TG, were compared. Applied preemergence, each herbicide controlled hairy bittercress, spotted spurge, and common groundsel for at least four weeks. These herbicides also controlled hairy bittercress and spotted spurge up to the four-leaf stage. Herbicides were less effective postemergence on common groundsel. Therefore, if all weeds are not hand removed from containers or if time passes between hand weeding and preemergence applications, BroadStar, OH2, or Snapshot TG can provide some early postemergence control but the level of control will depend upon the weed species, developmental growth stage of the plant, and the herbicide.

[1]Received for publication July 28, 2005; in revised form January 13, 2006. This research was funded in part by the North Carolina Agriculture Research Service, Raleigh, NC 27695-7643 and Valent U.S.A. Corp., P.O. Box 8025, Walnut Creek, CA 94596. The authors also thank Dow AgroSciences, 9330 Zionsville Rd., Indianapolis, IN 46268, and The Scotts Co., 14111 Scottslawn Road, Marysville, OH 43041, for donating chemicals used in this research. Statistical assistance of William Swallow is gratefully recognized. Use of trade names in this publication does not imply endorsement of products named nor criticism of similar ones not mentioned.

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### Introduction

Weeds can significantly reduce growth of containerized nursery crops (6, 7, 12). The dominant weed species in container-grown crops in the southeastern United States are primarily broadleaf weeds including hairy bittercress, spotted spurge, oxalis (*Oxalis* L. spp.), and eclipta [*Eclipta alba* (L.) Hassk.] (8, 10, 14). The container nursery industry relies upon frequent applications of broad-spectrum, preemergence herbicides, such as OH2 or Snapshot TG for weed control (16). Preemergence herbicides currently labeled for use in container nurseries are effective on common nursery weeds (7, 13, 20), but during nursery crop production in the southeastern United States, herbicides often dissipate rapidly (16), after which weeds begin to emerge. Emerged weeds in containers must be removed by hand before preemergence herbicides are reapplied, an expensive and laborious task (9, 14). In many situations it is not possible to completely remove all emerged weeds or to apply preemergence herbicides before new weed seedlings have emerged.

While preemergence herbicides are the principal option for broadleaf weed control in container nurseries, Altland et al. (1) reported early postemergence control of bittercress with spray applications of Gallery (isoxaben), a preemergence herbicide. The granular herbicide, Snapshot TG, also contains isoxaben but has not been tested for early postemergence control. Similarly, spray applications of Valor or SureGuard (flumioxazin) or Goal (oxyfluorfen) control many seedling broadleaf weeds (5, 18, 25). Anecdotal evidence suggests that BroadStar, a granular formulation of flumioxazin, and oxyfluorfen-containing granular herbicides such as OH2 may provide early postemergence control of common nursery weeds. Flumioxazin and oxyfluorfen are both protoporphyrinogen oxidase inhibitors (25) that can cause necrotic injury to crop foliage (hereafter referred to as burning) if granules are trapped on the leaf surface (2, 4, 25, 26). Snapshot TG affects weed growth by a different mode of action than flumioxazin or oxyfluorfen. Thus, it is considered a nonburning herbicide and used in the nursery industry where necrosis of the crop foliage needs to be avoided. Snapshot TG combines trifluralin, a seedling root inhibitor that inhibits microtubule function (25), with isoxaben, a cell wall synthesis inhibitor (15, 25). Therefore, the objective of this research was to compare early postemergence control of common broadleaf weeds with three preemergence nursery herbicides, BroadStar, OH2, and Snapshot TG.

## Materials and Methods

A container experiment was conducted in the greenhouse and was repeated twice outdoors to compare BroadStar 0.17G (Valent U.S.A. Corp., Walnut Creek, CA), flumioxazin at 0.28 kg ai/ha (0.25 lbs ai/A), OH2 3G (The Scotts Co., Marysville, OH), oxyfluorfen + pendimethalin at 3.4 kg ai/ha (3.0 lbs ai/A), and Snapshot TG 2.5G (Dow AgroSciences, Indianapolis, IN), isoxaben + trifluralin at 5.6 kg ai/ha (5.0 lbs ai/A). This experiment utilized the 0.17% active ingredient granular formulation of BroadStar at 0.28 kg ai/ha (0.25 lb ai/A) because it was conducted while the product was in development. The currently registered formulation is BroadStar 0.25G and the recommended application rate is 0.43 kg ai/ha (0.38 lb ai/A).

In the greenhouse experiment (2000) and the second outdoor experiment (2002), weed species evaluated were hairy bittercress, spotted spurge, and common groundsel. In the first outdoor experiment (2001), spotted spurge was not included because of poor seed germination. One pinch of weed seeds was surface-sown by hand to container substrates and grown in the absence of ornamental crops. Each species was grown in separate containers. Each herbicide was applied to each weed species at each of three growth stages: preemergence (greenhouse: September 12, 2000; outdoors 1: March 15, 2001; outdoors 2: May 30, 2002), cotyledon to one-leaf stage (greenhouse: September 22, 2000; outdoors 1: June 24, 2001; outdoors 2: June 26, 2002), and two- to four-leaf stage (greenhouse: October 2, 2000; outdoors 1: July 3, 2001; outdoors 2: July 2, 2002). Herbicides were applied using a hand-held shaker jar. For postemergence applications, foliage was dry at time of application.

In the greenhouse, containers were 15 cm (6 in) in diameter with volumetric capacity of 1.6 liters (0.4 gal) and were filled with a peat-based potting substrate (Fafard 4P, Fafard, Agawam, MA). In both outdoor experiments, 3.8 liter (#1) containers were filled with a 7:1 pine bark:sand substrate (v/v) amended with 3.6 kg/m$^3$ (6 lbs/yd$^3$) pulverized dolomitic limestone and 5.9 kg/m$^3$ (10 lbs/yd$^3$) Wilbro 15N–1.8P–7.5K controlled release fertilizer with micros (Harrell's, Lakeland, FL). Each experiment included a factorial arrangement of three herbicides, three application timings, and three species (two species in the first outdoor experiment) plus a nontreated control arranged in a randomized complete block design. In the greenhouse and the second outdoor experiment, there were 12 single-container replications, whereas in the first outdoor experiment, there were 10 single-container replications. In the greenhouse, containers were hand watered daily to container capacity. Outdoors, containers were irrigated overhead daily receiving two separate cycles each of approximately 8.5 mm (0.3 in).

Visual estimates of percent weed control were recorded 4 weeks after each application date using a 0 to 100% scale, where 0 equals no control and 100% equals complete weed control (11). Weed control was compared to nontreated plants accounting for both reduction in weed number and reduction in weed size. Nontreated plants covered the entire surface of the container substrate in all cases. Additionally, shoot fresh weights were recorded 4 weeks after final application for both the greenhouse and first outdoor experiment. These data were highly correlated ($r$ = 0.92); therefore, fresh weight measurements were determined to be unnecessary for the second outdoor experiment. Fresh weights from the greenhouse and first outdoor experiment are presented parenthetically transformed as a percentage of the nontreated fresh weights (Table 1).

All data were pooled across experiments. First, pairwise comparisons were performed for each treatment (each herbicide by timing combination averaged across species) with the nontreated control using analysis of variance ($P \leq 0.05$). Secondly, treatment main effects (herbicide, timing, and species) and all two-way and three-way interactions were determined by analysis of variance ($P \leq 0.05$) partitioning error appropriately for the factorial treatment design. Because spotted spurge was not included in one of the experiments, data were analyzed using two subsets. The first subset consisted of the greenhouse and the second outdoor experiments and included analysis of all three species (n = 24). The second subset consisted of all three experiments, but only tested hairy bittercress and common groundsel (n = 34). Where appropriate, treatment means were separated using Fisher's protected least significant difference at $P \leq 0.05$.

When ignoring the factorial arrangement of treatments and comparing the individual treatment combinations with nontreated plants, all treatments provided some level of control both preemergence and postemergence (data not presented). When considering the factorial arrangement of treatments and deleting the nontreated plants for data analysis, all main effects, two-way interactions, and the three way interactions were significant using either subset for data analysis. Thus, the nature of the two-way interactions is significantly different for each species and the effect of herbicide depends on both timing and species. Because of the three-way interaction and the missing data for spotted spurge, each species data were reanalyzed separately and presented separately herein.

## Results and Discussion

Four weeks after preemergence treatment, BroadStar, OH2, and Snapshot TG each controlled hairy bittercress ≥ 98%. Additionally, each herbicide controlled hairy bittercress ≥ 93% when applied at the cotyledon to one-leaf stage. Furthermore, BroadStar controlled hairy bittercress 89% when applied at the two- to four-leaf stage. OH2 and Snapshot TG were less effective controlling hairy bittercress at the two- to four-leaf stage, 71 and 78%, respectively (Table 1). A similar trend has been reported with sprayable isoxaben. Wild mustard (*Sinapsis arvensis* L), redroot pigweed (*Amaranthus retroflexus* L.), and common sunflower (*Helianthus annuus* L.) plants treated 7 to 10 days after planting were more susceptible to postemergence activity of isoxaben than those plants treated 12 and 14 days after planting (23). The authors determined that the magnitude of the response to isoxaben was more dependent on plant developmental stage than increasing rates of isoxaben.

Table 1. **Control of hairy bittercress, spotted spurge, and common groundsel with preemergence (Pre) or postemergence (Post) applications of BroadStar, OH2, or Snapshot TG. Visual estimates of percent control were recorded 4 weeks after each respective herbicide application.**

| | Application timing | | | |
|---|---|---|---|---|
| **Herbicide**[z] | **Pre** | **Post (0- to 1-leaf)** | **Post (2- to 4-leaf)** | **LSD** |
| | Hairy bittercress control (%[y])[x] | | | |
| BroadStar | 100 (100)[w] | 93 (89) | 89 (84) | 8 (11) |
| OH2 | 100 (98) | 96 (96) | 71 (68) | 8 (11) |
| Snapshot TG | 98 (100) | 96 (96) | 78 (63) | 8 (11) |
| LSD[v] | 8 (11) | 8 (11) | 8 (11) | |
| | Spotted spurge control (%) | | | |
| BroadStar | 98 (100) | 100 (100) | 79 (96) | 7 (6) |
| OH2 | 97 (100) | 91 (99) | 60 (77) | 7 (6) |
| Snapshot TG | 98 (100) | 99 (99) | 86 (84) | 7 (6) |
| LSD | 7 (6) | 7 (6) | 7 (6) | |
| | Common groundsel control (%) | | | |
| BroadStar | 99 (100) | 94 (90) | 70 (63) | 10 (14) |
| OH2 | 90 (83) | 81 (65) | 33 (32) | 10 (14) |
| Snapshot TG | 97 (88) | 48 (45) | 31 (30) | 10 (14) |
| LSD | 10 (14) | 10 (14) | 10 (14) | |

[z]Herbicide formulations and rates: Broadstar 0.17G (flumioxazin) applied at 0.28 kg ai/ha (0.25 lbs ai/acre), OH2 3G (oxyfluorfen + pendimethalin) applied at 3.4 kg ai/ha (3.0 lbs ai/acre), and Snapshot TG 2.5G (isoxaben + trifluralin) applied at 5.6 kg ai/ha (5.0 lbs ai/acre).

[y]Percent control was visually evaluated using a scale of 0 to 100% with 0 equal to no control and 100% equal to complete control.

[x]Data for hairy bittercress and common groundsel were pooled across one greenhouse and two outdoor experiment (n = 34). Spotted spurge data were pooled across one greenhouse and one outdoor experiment (n = 24).

[w]Percent control, in parenthesis, determined by fresh weights recorded 4 weeks after each respective herbicide application in the greenhouse experiment and the first outdoor experiment and transformed as a percent of the nontreated. Data for hairy bittercress and common groundsel were pooled across one greenhouse and one outdoor experiment (n = 22). Spotted spurge data is from one greenhouse experiment (n = 12).

[v]Fisher's protected least significant difference (LSD) at $P \leq 0.05$ for comparison of treatment means within a row or column. The LSD in parenthesis corresponds to the fresh weight data.

Four weeks after preemergence treatment, BroadStar, OH2, and Snapshot TG controlled spotted spurge ≥ 97%. BroadStar and Snapshot TG also controlled spotted spurge ≥ 99% when applied at the cotyledon to one-leaf stage. OH2 provided 91% control, which was significantly less than BroadStar and Snapshot TG. BroadStar and Snapshot controlled spotted spurge at the two- to four-leaf stage ≥ 79%. OH2 was less effective, providing only 60% control of spotted spurge (Table 1).

Four weeks after treatment, BroadStar, OH2, and Snapshot TG applied preemergence controlled common groundsel ≥ 90%. BroadStar applied at the cotyledon to one-leaf stage provided 94% common groundsel control, while OH2 provided 81% control, and Snapshot TG provided 48% control. Applied to common groundsel at the two- to four-leaf stage, BroadStar, OH2, and Snapshot TG provided 70, 33, and 31% control, respectively (Table 1).

The mode of postemergence action of these herbicides observed in this study is unclear. However, evidence exists for potential root uptake and injury to emerged plants by each herbicide tested. In our recent research, BroadStar applied to young, seedling wax myrtle [*Morella cerifera* (L.) Small] plants resulted in veinal anthocyanin accumulation in the new foliage followed by significant foliage necrosis whereas OH2 did not (unpublished data). Additionally, grape (*Vitis vinifera* L.) plants responded to flumioxazin in vitro, where the herbicide was active in photosynthetic tissues via root uptake (21). Limited oxyfluorfen root uptake has also been reported; however, it appears to be species dependent (24).

Though Snapshot TG is a nonburning herbicide, the isoxaben component has been shown to elicit herbicide activity on seedling redroot pigweed and wild mustard plants, and established ajuga (*Ajuga reptans* L., cv. Alba) and dwarf burning bush [*Euonymus alatus* (Thunb) Sieb., cv. Compacta] from root uptake (22, 23). Furthermore, Rossi et al. (19) reported early postemergence control of seedling smooth crabgrass [*Digitaria ischaemum* (Schreb.) Schreb. ex Muhl.] with pendimethalin, a dinitroaniline herbicide. Similarly, a granular formulation of dithiopyr, a mitotic inhibitor with a similar mode of action as the dinitroanilines, provided control of smooth crabgrass when applied postemergence to two- to four-leaf plants (17). Although the cellular mechanism of action is well understood, the mode of postemergence control from cell division inhibiting herbicides, otherwise considered to act preemergence, is not well understood. It is possible that the postemergence effectiveness of Snapshot TG was a combination of root uptake of isoxaben and/or root growth inhibition by the trifluralin component. Furthermore, it is possible that the postemergence effectiveness of OH2 was a combination of limited oxyfluorfen root uptake and/or growth inhibition by the pendimethalin component. Such postemergence action of these preemergence herbicides appears to differ among herbicides and weed species. But, as we have reported herein, postemergence activity of preemergence herbicides decreases as weeds develop.

In summary, the nursery herbicides BroadStar, OH2, and Snapshot TG provided excellent preemergence control of hairy bittercress, spotted spurge, and common groundsel. This observation was anticipated since these herbicides are all labeled for preemergence control of these species (2, 3, 4). Furthermore, BroadStar, OH2, and Snapshot TG provided effective postemergence control of hairy bittercress and spotted spurge when the plants were very small. These herbicides were less effective postemergence on common groundsel; however, BroadStar was twice as effective compared to OH2 and Snapshot TG. Consequently, if all weeds are not removed by hand from containers or if time passes between hand weeding and preemergence herbicide applications, such that seeds have time to germinate, BroadStar, OH2, or Snapshot TG can provide some early postemergence control depending on the weed species and growth stage of the weed.

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