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Preemergent Bittercress Control in Creeping Phlox (*Phlox subulata*)[1]

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Abstract

Preemergent herbicides that effectively control hairy bittercress are not labeled for use on creeping phlox. Studies were conducted to determine preemergent herbicide injury to creeping phlox varieties 'Crimson Beauty', 'Emerald Blue' and 'Fort Hill', and optimal herbicide rates for bittercress control. Barricade (prodiamine) applied at 0.55 kg ai/ha (0.5 lb ai/A) and Surflan (oryzalin) applied at 1.1 kg ai/ha (1.0 lb ai/A) severely injured creeping phlox. Injury was less severe from applications of Dimension (dithiopyr) at 0.83 kg ai/ha (0.75 lb ai/A), Gallery (isoxaben) at 0.55 kg ai/ha (0.5 lb ai/A), Image (imazaquin) at 0.55 kg ai/ha (0.5 lb ai/A), and Treflan (trifluralin) at 2.2 kg ai/ha (2.0 lb ai/A). Minimal to no injury was found with Pennant (metolachlor) at 2.2 kg ai/ha (2.0 lb ai/A) and Snapshot TG (isoxaben + trifluralin) at 2.8 kg ai/ha (2.5 lb ai/A). Two applications of Gallery at 0.28, 0.55 and 1.1 kg ai/ha (0.25, 0.50 and 1.0 lb ai/A), Pennant at 1.2, 2.2 and 4.4 kg ai/ha (1, 2 and 4 lb ai/A), RegalKade (prodiamine) at 0.28, 0.55 and 1.1 kg ai/ha (0.25, 0.50 and 1.0 lb ai/A), and Snapshot TG at 1.4, 2.8 and 5.5 kg ai/ha (1.3, 2.5 and 5.0 lb ai/A) did not affect growth of phlox varieties at 27 weeks after treatment (WAT). However, visual injury to varieties 'Crimson Beauty' and 'Fort Hill' was detected at a greater frequency than injury to 'Emerald Blue'. Gallery and Snapshot TG applied at 0.28, 0.55 and 1.1 kg ai/ha (0.25, 0.50 and 1.0 lb ai/A) and 1.4, 2.8 and 5.5 kg ai/ha (1.3, 2.5 and 5.0 lb ai/A), respectively, and RegalKade applied at 1.1 kg ai/ha (1 lb ai/A) provided excellent bittercress and yellow woodsorrel control at 8 and 12 WAT. Pennant did not control either weed species at the high rate. In a greenhouse study, Gallery applied at 0.14 kg ai/ha (0.13 lb ai/A) effectively controlled bittercress through 8 WAT, but Snapshot applied at the same rate of isoxaben did not control bittercress. Results indicate that Snapshot TG may be safely applied to creeping phlox at rates of 1.38 to 2.75 kg ai/ha (1.25 - 2.5 lb ai/A) for preemergent bittercress control. Gallery may also be used safely and effectively at rates of 0.14 to 0.28 kg ai/ha (0.13 to 0.25 lb ai/ A).

Index words: container nursery production, dinitroaniline herbicide, herbicide formulation, injury, phytotoxicity, preemergent herbicide, weed control, yellow woodsorrel.

Chemicals used in this study: Barricade (prodiamine), 2,4-dinitro-N^3, N^3-dipropyl-6-(trifluoromethyl)-1,3-benzenediamine; Dimension (dithiopyr), *S*,*S*-dimethyl 2-(difluoromethyl)-4-(2-methylpropyl)-6-(trifluoromethyl)-3,5-pyridinedicarbothioate; Gallery (isoxaben), *N*-[3-(1-ethyl-1-methylpropyl)-5-isoxazolyl]-2,6-dimethoxybenzamide; Image (imazaquin), 2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1*H*-imidazol-2-yl]-3-quinolinecarboxylic acid; Pennant (metolachlor), 2-chloro-*N*-(2-ethyl-6-methylphenyl)-*N*-(2-methoxy-1-methylethyl) acetamide; RegalKade (prodiamine), given above; Snapshot 2.5 TG (trifluralin + isoxaben), trifluralin = 2,6-dinitro-*N*,*N*-dipropyl-4-(trifluoromethyl)benzenamine, isoxaben = given above; Surflan A.S. (oryzalin), 4-(dipropylamino)-3,5-dinitrobenzenesulfonamide; Treflan 4HSP (trifluralin), given above.

Significance to the Nursery Industry

In the Southeast United States, liners of creeping phlox are transplanted into containers in early fall to produce salable plants the following spring. Hairy bittercress is a problem weed in container grown creeping phlox because optimal growing conditions for phlox coincide with ideal germination and growth conditions for bittercress. No preemergent herbicides that control bittercress are labeled for use on creeping phlox. These studies indicate that isoxaben provides excellent preemergent control of bittercress and may safely be applied to newly planted creeping phlox. However, optimal rates that will not injure creeping phlox vary with isoxaben formulation. Snapshot TG (granular formulation) applied to creeping phlox at 1.4 and 2.8 kg ai/ha (1.3 and 2.5 lb ai/A) did not produce long term injury to the three creeping phlox varieties tested, and adequately controlled bittercress under field production conditions. Gallery (sprayable formulation) did not injure phlox varieties when applied at a rate of 0.28 kg ai/ha (0.25 lb ai/ A), and excellent bittercress control was found when Gallery was applied at 0.14 kg ai/ha (0.13 lb ai/ A). Preemergent control of yellow woodsorrel was also excellent for Snapshot TG and Gallery applied at rates of 2.8 kg ai/ha (2.5 lb ai/ A) and 0.56 kg ai/ha (0.50 lb ai/ A), respectively. Though no injury to creeping phlox was detected from Pennant applied at 1.1 and 2.2 kg ai/ha (1 and 2 lb ai/A) and RegalKade applications at 0.28, 0.55 and 1.1 kg ai/ha (0.25, 5 and 1 lb ai/A), bittercress control was inadequate except for the highest rate of RegalKade. Creeping phlox were severely injured by Barricade at 0.55 kg ai/ha (0.5 lb ai/A) and Surflan at 2.2 kg ai/ha (2.0 lb ai/A).

Introduction

Creeping phlox is a major perennial crop of container nurseries. In 1998, 2.7 million containers of phlox species were produced in the United States with sales totaling over $7 million (USDA, 1998 Census of Horticultural Specialties). Production of salable containers in the Southeastern states begins with planting of rooted liners in the early fall to produce full containers for sale the following spring. Hairy bittercress is a major weed problem in containerized phlox as optimal growing conditions for the crop coincide with optimal growth conditions for the weed.

Bittercress (*Cardamine hirsuta* L.), a member of the Brassicaceae (mustard) family, behaves as a winter annual

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in the wild but will germinate year-round in the container nursery environment under production conditions of daily irrigation and regular fertilization. Bittercress plants mature, flower, develop siliques and release seeds in as short a period as 4 to 5 weeks, and each plant can produce up to 5000 seeds that are forcefully propelled for a distance of up to 1 m (42 in) (2). Significant bittercress infestations may occur in a short period of time. Excellent preemergent bittercress control has been achieved with many preemergent herbicides applied at 2 and 4× label rates (4, 16). Effective control also resulted from Rout (oxyfluorfen + oryzalin), Ronstar (oxadiazon), and Ronstar + Princep (simazine) applied at ½× recommended rates (12).

Injury to herbaceous perennials following applications of preemergent herbicides has been the subject of several studies. Porter (11) investigated isoxaben and isoxaben combination herbicides for weed control in containerized herbaceous perennials and found that Snapshot TG (isoxaben + trifluralin) did not injure the tested species, but Gallery (isoxaben) applied at 1.1 kg ai/ha (1.0 lb ai/A) injured 'Alaska' shasta daisy (*Chrysanthemum maximum* Ramond), 'Autumn Glory' chrysanthemum (*Chrysanthemum* sp.), 'McKana Giant' columbine (*Aquilegia* spp.), gloriosa daisy (*Rudbeckia hirta* L.), 'Summer Carnival' hollyhock (*Althaea rosea* L.), 'Giant Mixed' painted daisy (*Chrysanthemum coccineum* Wild.), and 'Summer pastels' yarrow (*Achillea millifolium* L.) at 4 weeks after treatment (WAT). An application of Rout 3G reduced growth of wooly yarrow (*Achillea tomentosa* L.), and wooly thyme (*Thymus pseudolanuginosus* Ronn.) was injured by Devrinol 10G (napropamide), Pennant 5G (metolachlor), Ronstar 2G, Rout 3G and Treflan 5G (trifluralin) (14). Surflan (oryzalin) and Snapshot TG applied at 1 and 2× maximum rates injured container-grown Shasta daisy (*Chrysanthemum xsuperbum* Bergmans ex. J. Ingram), lanceleaf coreopsis (*Coreopsis lanceolata* L.), purple coneflower (*Echinacea purpurea* (L.) Moench.), black-eyed Susan (*Rudbeckia hirta var. pulcherrima* Faew.) and blanket flower (*Gallardia aristata* Pursh) four WAT (7). Two herbaceous groundcovers, common periwinkle (*Vinca minor* L.) and greater periwinkle (*Vinca major* L.), were not injured by Barricade (prodiamine) or Ronstar (9). Field grown 'Omega' wild sweet William (*Phlox maculata* L. 'Omega') tolerated Ronstar 50WP but was injured more severely than other perennials by Gallery, Goal, Rout and Surflan (5). Surflan reduced height of perennial phlox (*Phlox paniculata* L.), and lamb's ear (*Stachys byzantina* C. Koch) was injured by Gallery (15). Ronstar and OH-2 (oxyfluorfen + pendimethalin) applied bimonthly resulted in slight injury to field-grown creeping phlox at 218 days, but Betasan (bensulide), Balan (benefin), Devrinol, Dacthal (DCPA) and Pennant produced no injury (13).

Though many herbicides are labeled for preemergent bittercress control, none are labeled for use on creeping phlox. The objective of this research was to determine short and long term injury to creeping phlox varieties following single and repeat applications of preemergent herbicides. An additional goal was the evaluation of reduced herbicide rates for control of bittercress.

Materials and Methods

Experiment 1. Herbicide screening study. In the summer of 2001, a study was conducted at the Clemson Nursery Research Area located on the campus of Clemson University to determine injury to creeping phlox from preemergent herbicide applications. Eight commercially available herbicide formulations were applied to three varieties of creeping phlox. Treatments were Barricade 65WG at 0.55 kg ai/ha (0.5 lb ai/A), Dimension 1EC at 0.83 kg ai/ha (0.75 lb ai/A), Gallery 75 DF at 0.55 kg ai/ha (0.5 lb ai/A), Image 1.5 SL at 0.55 kg ai/ha (0.5 lb ai/A), Pennant 7.8 EC at 2.2 kg ai/ha (2 lb ai/A), Snapshot 2.5 TG at 2.8 kg ai/ha (2.5 lb ai/A), Surflan A.S. at 2.2 kg ai/ha (2 lb ai/A), and Treflan HSP at 2.2 kg ai/ha (2.0 lb ai/A). Uniform liners of creeping phlox varieties 'Crimson Beauty', 'Emerald Blue' and 'Fort Hill' were obtained from Yoder® Brothers, Inc./Green Leaf Perennials™ (2369 Old Philadelphia Pike, Lancaster, PA). Liners were potted into #1 (4 liter) containers on July 2. The substrate was pine bark:peanut hulls:peat (60:25:15 by vol) amended with 2.7 kg (6 lb) lime, 0.9 kg (2 lb) gypsum, and 3.6 kg (8 lb) of a complete starter fertilizer (Nutricote Total 180 day $18NO_3$–$6P_2O_5$–$8K_20$) per cu m (cu yd). Herbicide treatments were applied on July 3. Granular herbicides were applied with a hand-held shaker can and sprayable herbicides were applied with a CO_2 pressurized backpack sprayer fitted with 8003 nozzles calibrated to deliver 187 liters/ha (20 gal/A) at 40 psi. There were five replications of each of the eight herbicide treatments and the untreated control. Overhead irrigation was applied daily in three pulse cycles of 20 min each with a 2.5 h rest between cycles. Total irrigation applied was 2 cm (0.8 in) per day. Masterblend $20N(12NO_3; 8NH_3)$–$10P_2O_5$–$8K_20$ soluble fertilizer was applied biweekly to phlox throughout the growing season.

Visual injury was evaluated at 1, 6, 8, and 13 weeks after herbicide application (WAT). Injury was rated on a scale of 0 to 100 where 0 = no injury and 100 = plant death. Untreated plants received an injury rating of 0 and treated plants were compared to untreated on all rating dates. Minimal injury (5 to 25%) was assigned when slight growth reduction (internode shortening) was observed; moderate injury ratings (26 to 50%) manifested as noticeable growth reduction and mild chlorosis of shoots; severe injury ratings (51 to 75%) were assigned when no new plant growth was observable and/or plants were uniformly chlorotic; injury ratings of 76 to 100% were assigned to plants that produced no new growth following treatment, and old growth became necrotic. At 13 WAT growth indexes were compiled by measuring width of plants at widest point and 90° to widest point and dividing the sum by two. At this time, top growth of the phlox was removed at the substrate surface, fresh weights were recorded, and after drying at 40C for 7 d, dry weights were noted. Injury was also visually measured as compared to untreated plants at 40 WAT, in March 2002, to determine long term effects of herbicide application on plant health.

Experiment 2. Herbicide rate study. Herbicides that minimally injured creeping phlox in the initial study were further evaluated for injury and bittercress control in a second study. Treatments were Gallery 75 DF at 0.28, 0.55 and 1.1 kg ai/ha (0.25, 0.50 and 1.0 lb ai/A), Pennant 7.8 EC at 1.2, 2.2 and 4.4 kg ai/ha (1, 2 and 4 lb ai/A), RegalKade G at 0.28, 0.55 and 1.1 kg ai/ha (0.25, 0.50 and 1.0 lb ai/A), and Snapshot 2.5 TG at 1.4, 2.8 and 5.5 kg ai/ha (1.3, 2.5 and 5.0 lb ai/A). RegalKade G was added to this study as prodiamine provides excellent bittercress control (3, 16), and postulated was that a granular formulation may produce less injury than the sprayable prodiamine formulation evaluated in the initial

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Table 1. Visual injury (%) on creeping phlox varieties at 1, 6 and 13 weeks after treatment (WAT) with preemergent herbicides applied at label rates in the herbicide screening study.

			Injury (%)								
	Rate		'Crimson Beauty'			'Emerald Blue'			'Fort Hill'		
Herbicide	kg ai/ha	lb ai/A	1WAT	6WAT	13WAT	1WAT	6WAT	13WAT	1WAT	6WAT	13WAT
Barricade 65WG (prodiamine)	0.55	0.5	16	72	82	13	64	82	12	50	64
Dimension 1EC (dithiopyr)	0.83	0.75	7	50	16	2	32	16	0	20	15
Gallery 75 DF (isoxaben)	0.55	0.5	14	43	22	0	26	8	24	24	20
Image 1.5 SL (imazaquin)	0.55	0.5	21	39	20	18	30	18	8	18	16
Pennant 7.8 EC (metolachlor)	2.2	2.0	10	34	6	2	4	0	5	24	6
Snapshot 2.5 TG (trifluralin + isoxaben)	2.8	2.5	0	0	0	5	4	2	2	4	4
Surflan A.S. (oryzalin)	2.2	2.0	14	82	100	9	46	82	13	66	86
Treflan HSP (trifluralin)	2.2	2.0	14	25	8	2	36	18	4	28	28
Untreated	0	0	0	0	0	0	0	0	0	0	0
LSD ($P = 0.05$)			8	17	19	7	15	10	8	15	19

screening study. Creeping phlox varieties were the same as in the first study. Liners from Yoder Bros. were transplanted into #1 (4 liter) containers on September 4. Substrate composition, herbicide application on the day after planting, and growing conditions were as described for the first study. There were five replications of the 12 herbicide treatments and an untreated control arranged in a randomized complete block design within a species. Visual injury was rated at 1, 4, 8, and 12 WAT. Herbicides were reapplied to treatments on December 4 (15 WAT) and injury was rated on 22 and 27 weeks after initial treatment (7 and 12 weeks after second treatment). At the end of the study, 27 WAT, growth index of containerized phlox was determined by measuring two widths (at widest point and 90º to widest point) and height, and calculated as the width average + height / 2.

To evaluate bittercress control, three unplanted containers of each herbicide treatment and an untreated control were seeded with bittercress at the rate of 100 seeds per container 3 days after herbicide application. Weed control was rated at 8 and 12 WAT on a scale of 0 to 100 with 0 = no control and 100 = complete control. Bittercress control was also evaluated at 8 and 12 WAT in the containerized phlox. Natural populations of yellow woodsorrel (*Oxalis stricta*) developed rapidly in the containers and control was rated as described for bittercress.

Experiment 3. Bittercress control study. A greenhouse study was conducted in December 2001 through March 2002 to determine if reduced herbicide rates would control bittercress. Treatments were Gallery 75 DF at 0.14, 0.28 and 0.55 ai/ha (0.13, 0.25 and 0.50 lb ai/A), RegalKade G at 0.14, 0.28 and 0.55 kg ai/ha (0.13, 0.25 and 0.50 lb ai/A), and Snapshot 2.5 TG at 0.7, 1.38 and 2.75 kg ai/ha (0.63, 1.25 and 2.5 lb ai/A). Herbicides were applied to #SP-4 (10 cm; 4 in) pots containing only the substrate previously described. There were 10 treatments including the untreated control, with 15 replications of each treatment arranged in a randomized complete block design. Treated containers were placed in a greenhouse maintained at 16C (60F) night temperature and 24C (75F) day temperature. Mist irrigation was applied three times per day at a duration of four min for each application. Containers (#1) of mature flowering bittercress were placed on 46 × 46 cm (18 × 18 in) centers within the replications to provide a constant source of bittercress seed. Soluble fertilizer (Masterblend 20N($12NO_3$; $8NH_3$)–$10P_2O_5$–$8K_20$) was applied weekly to the containers. Bittercress control was visually evaluated at 4, 8, and 10 WAT on the scale described above. At 10 WAT, bittercress plants were harvested from 7 replications and fresh weights were taken; 5 weeks later (15 WAT) bittercress plants were harvested from the 8 remaining replications and fresh weights were noted.

Statistical design was a randomized complete block within each variety of creeping phlox and unplanted containers. Data from the studies were subjected to ANOVA and means for sampling dates were separated using least significant differences at $P = 0.05$.

Results and Discussion

Experiment 1. Herbicide screening study. Barricade and Surflan severely injured all phlox varieties at 13 WAT, while Pennant applied at 2.2 kg ai/ha (2 lb ai/A) and Snapshot TG applied at 2.8 kg ai/ha (2.5 lb ai/A) did not injure or reduce shoot growth of the three phlox varieties (Tables 1, 2). However, results indicate that tolerance of preemergent herbicides may differ for varieties of creeping phlox. At 1 WAT, phlox variety 'Crimson Beauty' was injured by Barricade, Gallery, Image, Pennant, Surflan and Treflan (Table 1). At 6 WAT, injury was greater than the untreated control for all herbicide treatments except Snapshot TG. By 13 WAT, Barricade and Surflan treated 'Crimson Beauty' containers were severely injured (>82%); however, Pennant, Snapshot TG and Treflan treated plants had only slight injury (<8%). 'Emerald Blue' phlox was injured by Barricade, Image and Surflan at 1 WAT (Table 1). At 6 WAT, injury was greater than the untreated control for all herbicide treatments except Pennant and Snapshot TG. At 13 WAT, Barricade and Surflan treatments displayed extensive injury (82%), but Gallery, Pennant and Snapshot TG treatments were unaffected and similar to untreated plants. Phlox variety 'Fort Hill' was injured by Barricade, Gallery, Image and Surflan treatments at 1 WAT (Table 1). At 6 and 13 WAT, >50% injury was detected in the Barricade and Surflan treatments. At 13 WAT, Gallery, Pennant and Snapshot TG injury was minimal and similar to untreated plants (<16%).

For all phlox varieties, GI and shoot dry weight from the Snapshot TG treatment were similar to that of untreated plants (Table 2). Pennant did not affect GI of any phlox variety but reduced dry weight of 'Crimson Beauty'. Gallery reduced GI and dry weight of 'Crimson Beauty' and 'Fort Hill' but

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Table 2. Growth index (cm) and shoot dry weight (g) at 13 weeks after treatment (WAT), and visual injury (%) at 40 WAT of creeping phlox varieties 'Crimson Beauty' (CrB), 'Emerald Blue' (EmB), and 'Fort Hill' (FtH) treated with preemergent herbicides applied at label rates in the herbicide screening study.

Herbicide	Rate		Growth index (cm)			Dry weight (g)			Injury (%), 40 WAT		
	kg ai/ha	lb ai/A	CrB	EmB	FtH	CrB	EmB	FtH	CrB	EmB	FtH
Barricade 65WG (prodiamine)	0.55	0.5	10.6	7.1	11.2	2.1	2.0	6.2	100	100	92
Dimension 1EC (dithiopyr)	0.83	0.75	29.0	12.7	19.6	23.0	6.2	11.9	47	80	62
Gallery 75 DF (isoxaben)	0.55	0.5	30.5	15.4	16.9	20.4	8.5	9.6	42	47	35
Image 1.5 SL (imazaquin)	0.55	0.5	28.7	13.6	16.9	13.1	6.9	12.5	35	50	40
Pennant 7.8 EC (metolachlor)	2.2	2.0	34.7	17.8	21.1	25.8	10.6	18.4	25	62	40
Snapshot 2.5 TG (trifluralin + isoxaben)	2.8	2.5	43.3	16.8	21.1	41.6	8.0	16.9	35	47	47
Surflan A.S. (oryzalin)	2.2	2.0	0	7.1	5.6	0.1	1.3	1.3	100	100	100
Treflan HSP (trifluralin)	2.2	2.0	34.4	13.6	16.4	25.4	6.7	10.8	70	100	100
Untreated	0	0	42.2	17.3	22.6	40.4	9.2	20.6	0	0	0
LSD ($P = 0.05$)			7.6	3.0	3.8	9.4	1.8	4.5	41	45	40

did not affect growth of 'Emerald Blue'. Barricade, Image, Surflan and Treflan treatments reduced GI and shoot dry weight of all phlox varieties. Dimension reduced GI of all varieties except 'Fort Hill'. Varietal response differences to the herbicides may be related to the vigor and growth rate of the varieties. At 13 WAT, shoot dry weight of 'Crimson Beauty' was four times greater than that of 'Emerald Blue' and twice as large as 'Fort Hill', and GI of 'Crimson Beauty' was twice as large as that of the other varieties. 'Emerald Blue' was tolerant of Gallery applications but the more rapidly growing creeping phlox varieties were not. This contrasts with results reported by Staats et al. (14) in which herbicide injury to woolly thyme was attributed to a less vigorous growth habit.

Regrowth of containerized phlox was evaluated visually for injury the following spring at 40 WAT (27 weeks after shoots were harvested). All untreated plants were healthy, salable and flowering. Shoots of herbicide treated plants were stunted and chlorotic as compared to the untreated, and flowering was minimal. Barricade, Surflan and Treflan treatments had ≥ 90% injury (Table 2). Injury was also high for the Dimension treatment (>63%). Moderate injury was found for the Gallery, Image, Pennant and Snapshot TG treated phlox (41% to 43%).

These results concur with those reported by other researchers. Barricade and Surflan reduced growth of a variety of container-grown herbaceous perennials (7, 9, 15, 16). Injury to perennial phlox (*Phlox paniculata*) was severe from a Surflan application at 2.8 and 4.5 kg ai/ha (2 and 4 lb ai/A) (15). Image applied at 0.28 kg ai/ha (0.25 lb ai/A) reduced growth of liriope (*Liriope muscari*) (1). Pennant has been evaluated for use on herbaceous perennials with minimal to no injury reported (5, 6, 14). Skroch et al. (13) reported Pennant (3 lb ai/A) did not injure creeping phlox 218 DAT but no phlox variety was specified. However, injury to field-grown wild sweet William (*Phlox maculata* 'Omega') was severe from a Pennant application at the maximum use rate of 3.36 kg ai/ha (3.0 lb ai/A) (5). Snapshot TG applied at 5.6 kg ai/ha (5.0 lb ai/A) injured container-grown hollyhock and painted daisy, but did not injure shasta daisy, chrysanthemum, columbine, coreopsis, gloriosa daisy, hibiscus or yarrow (11). Derr (7) reported reduced shoot fresh weight in Shasta daisy 3 months after treatment from applications of Snapshot TG at 5.6 and 11.2 kg ai/ha (5.0 and 10.0 lb ai/A), although lanceleaf coreopsis, purple coneflower, black-eyed Susan and blanket flower were not affected. Injury from Gallery applications has been reported for a number of herbaceous perennials including lamb's quarters, painted daisy and wild sweet William (5, 15).

Experiment 2. Herbicide rate study. At 27 WAT, creeping phlox varieties were not visually injured by two applications of Pennant at 1.1 and 2.2 kg ai/ha (1 and 2 lb ai/A), RegalKade at 0.28, 0.55 and 1.1 kg ai/ha (0.25, 0.50 and 1 lb ai/A), and Snapshot TG at 1.4 and 2.8 kg ai/ha (1.3 and 2.5 lb ai/A) (Table 3). On all rating dates, phlox variety 'Crimson Beauty' was injured by Gallery at 0.55 and 1.1 kg ai/ha (0.5 and 1 lb ai/A) and Pennant at 4.4 kg ai/ha (4 lb ai/A) (Table 3). Snapshot TG injury was observed at 27 WAT from the high rate treatment [5.5 kg ai/ha (5 lb ai/A)] and RegalKade injury was noted at 22 WAT from the high rate application [1.1 kg ai/ha (1 lb ai/A)]. However, 'Crimson Beauty' GI at the end of the study (27 WAT) was unaffected by all treatments except for Pennant at 4.4 kg ai/ha (4 lb ai/A) (Table 3). 'Emerald Blue' was injured only by the high rate of Snapshot TG at 27 WAT (Table 3). Though early injury to 'Emerald Blue' was caused by Snapshot TG (high rate) and RegalKade (medium rate) (data not shown), GI at the end of the study (27 WAT) was unaffected by all treatments and was similar to or greater than that of untreated plants (Table 3). Creeping phlox variety 'Fort Hill' was injured by Gallery applications at 0.55 and 1.1 kg ai/ha (0.5 and 1.0 lb ai/A) on all rating dates, and from the low Gallery application rate [0.28 kg ai/ha (0.25 lb ai/A)] at 12 and 22 WAT (Table 3). Snapshot TG at 5.5 kg ai/ha (5 lb ai/A) injured 'Fort Hill' at 1, 12, 22 and 27 WAT, and early injury (1 and 4 WAT) was detected for RegalKade applied at 0.28 kg ai/ha (0.25 lb ai/A) (1 and 4 WAT rating data not shown). Despite noted visual treatment injury at the end of the study, the GI of 'Fort Hill' was unaffected by all treatments except for Gallery at 1.1 kg ai/ha (1 lb ai/A) (Table 3).

Excellent control of hairy bittercress was obtained with all Gallery and Snapshot TG rates at 8 and 12 WAT (Table 4). RegalKade at 1.1 kg ai/ha (1 lb ai/A) also provided >90% bittercress control. Yellow woodsorrel was controlled >86% by Snapshot TG (all rates), Gallery at 0.55 and 1.1 kg ai/ha (0.5 and 1.0 lb ai/A) and RegalKade at 1.1 kg ai/ha (1.0 lb ai/A) (Table 4). Pennant applied at all rates and RegalKade applied at low and medium rates did not provide adequate hairy bittercress or yellow woodsorrel control. These results support previous reports. Barricade applied at 0.8 and 1.7 kg ai/

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Table 3. Visual injury (%) of creeping phlox varieties 'Crimson Beauty' (CrB), 'Emerald Blue' (EmB) and 'Fort Hill' (FtH) at 12, 22 and 27 weeks after treatment (WAT) with preemergent herbicides, and growth index (GI) (cm) at 27 WAT for the herbicide rate study. Containers received a second application of herbicide at 15 WAT.

			'Crimson Beauty'			'Emerald Blue'			'Fort Hill'			CrB	EmB	FtH
	Rate		Injury (%) (WAT)									GI (cm)		
Herbicide	kg ai/ha	lb ai/A	12	22	27	12	22	27	12	22	27	27WAT		
Gallery 75 DF (isoxaben)	0.28	0.25	0	0	0	6	3	3	6	16	15	19.5	13.5	14.2
	0.55	0.50	48	35	20	12	13	10	20	25	30	16.5	12.2	12.3
	1.1	1.0	50	40	16	28	18	0	20	38	28	16.0	12.4	11.6
Pennant 7.8 EC (metolachlor)	1.1	1.0	13	0	0	4	8	5	4	6	3	20.8	13.4	14.6
	2.2	2.0	12	10	3	10	13	13	0	8	0	18.7	12.2	15.2
	4.4	4.0	63	50	30	14	10	5	2	13	3	14.0	13.1	14.5
RegalKade G (prodiamine)	0.28	0.25	2	0	3	2	0	0	14	3	10	20.6	15.3	14.4
	0.55	0.50	8	0	0	12	10	10	10	9	8	21.1	13.6	14.3
	1.1	1.0	15	15	13	8	6	8	10	3	5	17.6	12.6	13.8
Snapshot 2.5 TG (trifluralin + isoxaben)	1.4	1.3	15	5	8	4	8	5	5	10	10	19.1	12.4	13.5
	2.8	2.5	11	0	3	0	3	0	2	10	5	19.2	14.9	13.6
	5.5	5.0	18	13	18	8	10	15	22	15	25	17.1	12.1	13.0
Untreated	0	0	0	0	0	0	0	0	0	0	0	17.8	13.3	13.7
LSD ($P = 0.05$)			17	15	15	13	15	14	12	15	12	3.0	2.1	1.9

ha (0.7 and 1.6 lb ai/A) provided excellent control of yellow woodsorrel, though control was inadequate from Pennant applied at 4.5 kg ai/ha (4.0 lb ai/A) (7). Excellent bittercress control from sprayable and granular formulations of prodiamine was obtained at high (2 to 4×) label rates (3, 16). Snapshot TG applied at 5.6 and 11.2 kg ai/ha (5.0 and 10.0 lb ai/A) provided 100% control of yellow woodsorrel at 2 months after treatment (7). Gallery applied at 1.1 kg ai/ha (1.0 lb ai/A) controlled bittercress for 6 months (8), and reduced density of broadleaf weeds by 92% (5).

Experiment 3. Bittercress control study. Gallery applied at all rates provided excellent bittercress control through 8 WAT (Table 5). At 4 WAT Gallery applied at 0.14 kg ai/ha (0.125 lb ai/A) provided 78% bittercress control, similar to results obtained with higher rates. At 8 WAT, all Gallery treatments adequately controlled bittercress (>87%), though at 10 WAT, a decline in control was observed (76% average control). Snapshot TG provided greater bittercress control when applied at medium and high rates than at the low rate. Average bittercress control was 50% at 4 WAT and 62% at 8 WAT with the medium and high Snapshot TG rate treatments, but by 10 WAT, control had dropped to an average of 30%. RegalKade treatments did not control bittercress effectively at 4, 8 or 10 WAT. Fresh weight of bittercress seedlings at 10 WAT was greatly reduced for all Gallery treatments as compared to untreated containers (Table 5). Seedling weight average was <5% of the untreated. However, control declined thereafter and at 15 WAT fresh weight of Gallery treatments was 50% of that of the untreated pots. Fresh weight of bittercress seedlings in the RegalKade and Snapshot TG treatments was 68% and 36%, respectively, of the untreated control at 10 WAT, and 48% and 65% at 15 WAT. The sprayable formulation (Gallery) of isoxaben was more efficacious than the granular formulation (Snapshot TG) though isoxaben rates were identical. This differs from previous field research in which formulations were determined to be equally effective for bittercress control (4). This may be the result of condi-

Table 4. Hairy bittercress and yellow woodsorrel control (%) in containers at 8 and 12 weeks after treatment (WAT) with preemergent herbicides in the herbicide rate study. Control is an average for the three phlox varieties and the empty containers seeded with bittercress.

			Control (%)			
	Rate		Bittercress		Yellow woodsorrel	
Herbicide	kg ai/ha	lb ai/A	8WAT	12WAT	8WAT	12WAT
Gallery 75 DF (isoxaben)	0.28	0.25	97	98	86	79
	0.55	0.50	100	99	99	96
	1.1	1.0	100	100	98	96
Pennant 7.8 EC (metolachlor)	1.1	1.0	54	65	16	45
	2.2	2.0	69	74	42	52
	4.4	4.0	79	69	76	71
RegalKade G (prodiamine)	0.28	0.25	63	72	43	57
	0.55	0.50	73	79	74	88
	1.1	1.0	92	90	97	99
Snapshot 2.5 TG (trifluralin + isoxaben)	1.4	1.3	98	98	86	91
	2.8	2.5	99	99	97	99
	5.5	5.0	100	100	100	100
Untreated	0	0	0	0	0	0
LSD ($P = 0.05$)			11	11	16	9

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Table 5. Hairy bittercress control (%) at 4, 8 and 10 weeks after treatment (WAT) with preemergent herbicides, and fresh weight (g) of bittercress plants per pot at 10 and 15 WAT in the bittercress control greenhouse experiment.

			Bittercress				
	Rate		Control (%)			Fresh weight (g)	
Herbicide	kg ai/ha	lb ai/A	4WAT	8WAT	10WAT	10WAT	15WAT
Gallery 75 DF (isoxaben)	0.14	0.13	78	91	84	0.02	1.5
	0.28	0.25	84	90	73	0.25	2.8
	0.55	0.50	87	87	70	0.32	2.0
RegalKade G (prodiamine)	0.14	0.13	13	17	3	2.7	3.1
	0.28	0.25	23	22	1	2.8	3.1
	0.55	0.50	29	43	21	3.5	3.0
Snapshot 2.5 TG (trifluralin + isoxaben)	0.70	0.63	39	41	13	1.7	2.9
	1.38	1.25	47	59	24	1.7	2.4
	2.75	2.50	52	64	35	1.5	2.9
Untreated	—	—	0	0	0	4.4	4.2
LSD ($P = 0.05$)			12	11	11	1.3	1.0

tions under which the current experiment was conducted. Mist irrigation maintained constant substrate moisture levels that may have expedited release from the granule resulting in reduced weed control. Also, the low granular rate may have inadequately covered the substrate surface allowing seedling establishment. However, results confirm previous reports on the effectiveness of low rates of isoxaben in controlling broadleaf weeds. Gallery applied at 0.56 kg ai/ha (0.5 lb ai/ A) provided excellent control of summer and winter annual broadleaf weeds in containers 8 WAT (10).

These studies indicate that isoxaben provides excellent preemergent control of bittercress and may safely be applied to creeping phlox. However, optimal rates that are non-injurious to creeping phlox vary with isoxaben formulation. Snapshot TG (granular formulation) applied to creeping phlox at rates of 1.38 to 2.75 kg ai/ha (1.25–2.5 lb ai/A) did not produce long term injury to the three creeping phlox varieties tested and adequately controlled bittercress under field production conditions. Gallery (sprayable formulation) applied at 0.56 kg ai/ha (0.50 lb ai/ A) produced minor long-term injury in 'Crimson Beauty' and 'Fort Hill' phlox varieties, but did not injure 'Emerald Blue', and did not injure any phlox variety when applied at a lower rate of 0.28 kg ai/ha (0.25 lb ai/ A). Excellent bittercress control was found when Gallery was applied at 0.14 kg ai/ha (0.13 lb ai/A). Preemergent control of yellow woodsorrel was excellent from Snapshot TG and Gallery applications at rates of 2.75 kg ai/ha (2.5 lb ai/A) and 0.56 kg ai/ha (0.50 lb ai/ A), respectively. Gallery is also reported to be effective for postemergent control of immature bittercress at a rate of 1.1 kg ai/ha (1.0 lb ai/ A) (1). Though no injury to creeping phlox was detected from Pennant and RegalKade applications at label rates, bittercress control was inadequate.

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