Early Postemergence Control of Spotted Spurge in Container Production[1]

S. Christopher Marble[2], Charles H. Gilliam[3], Glenn R. Wehtje[4], Albert J. Van Hoogmoed[2], and Cristi Palmer[5]
Department of Horticulture, Auburn University
Auburn, AL 36849

Abstract

Four experiments were conducted to evaluate early postemergence control of spotted spurge (*Chamaesyce maculata*) in nursery crops using preemergence active herbicides. In Experiment 1, spotted spurge (SS) seed were overseeded at two different dates in a commercial pine bark substrate and were grown until reaching either the cotyledon to one leaf (C–1L) stage, or the two to four leaf (2–4L) stage. Herbicides applied included: Broadstar 1604 (flumioxazin), V-10142 (imazosulfuron), and Tower (dimethenamid-P). These products were applied postemergence at their respective recommended label rate (1×) and twice (2×) this rate to SS either at the C–1L stage or at the 2–4L stage. In general, V10142 and Tower provided the greatest injury to SS in the C–1L. Tower also provided greatest SS injury in the 2–4L stage. In Experiment 2, postemergence control was tested in the C1-L and 2–4L stages with Broadstar 1604, FreeHand (dimethenamid-P 0.75% + pendimethalin 1.0%), Tower, and Pendulum 3.3 EC (pendimethalin) at the 1× and 2× the label rate. FreeHand at 2×, along with Tower and Pendulum at both rates provided the highest SS injury ratings in the C–1L. Tower at 2× and Pendulum at both rates provided greatest SS injury in the 2–4L. In Experiments 3 and 4, Broadstar (1/2×, 1×, and 2× rate), Casoron (dichlobenil) (1× and 2×), HGH-63 (oxyflurfen) (1×), Certainty (sulfosulfuron) (1× and 2×), Tower (2/3× and 1×), V-10142 (1× and 2×), Pendulum 3.3 EC (1× and 2×), FreeHand (1× and 2×) were applied to SS in either C–1L or 2–4L as described above. Results from Experiments 3 and 4 indicate that Certainty (both rates), Tower (both rates), Pendulum (both rates), and FreeHand (both rates) have postemergence activity on immature SS, especially when applied in the C–1L stage. Postemergence activity declined when herbicides were applied to SS in the 2–4L, however Pendulum (both rates), Certainty (both rates), and FreeHand (2× rate) had a marginal effect.

Index words: weed control, nursery production.

Herbicides used in this study: Broadstar 0.25G (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); V10142 0.5G (imazosulfuron) 1-(2-chloroimidazo[1,2-*a*]pyridin-3-ylsulfonyl)-3-(4,6 dimethoxypyrimidin-2-yl)urea; Tower 6.0 EC (dimethenamid-P) (*S*)-2-chloro-*N*-(2,4-dimethyl-3-thienyl)-*N*-(2-methoxy-1-methylethyl) acetamide; FreeHand 1.75G (dimethenamid + pendimethalin) (*S*)-2-chloro-*N*-(2,4-dimethyl-3-thienyl)-*N*-(2-methoxy-1-methylethyl) acetamide + N-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine; Pendulum 3.3 EC (pendimethalin) N-(1-ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine; Casoron 4G (dichlobenil) 2,6-dichlorobenzonitrile; HGH-63 2G (oxyfluorfen) 2-chloro-1-(3-ethoxy-4-nitrophenoxy)-4-(trifluoromethyl) benzene; and Certainty 75 WDG (sulfosulfuron) N-[[(4,6-dimethoxy-2-pyrimidinyl) amino]carbonyl]-2-(ethylsulfonyl)imidazo[1,2-a]pyridine-3-sulfonamide.

Species evaluated in this study: spotted spurge (*Chamaesyce maculata* L.).

Significance to the Nursery Industry

Spotted spurge (SS) is a major weed in container production in the United States. The prolifically produced seeds have no dormancy requirement and germinate quickly. Spotted spurge is most often controlled using preemergent applied herbicides, but containers must be weed free prior to herbicide application for these products to be effective. It is often difficult to remove all emerged SS prior to herbicide application because of their color and low growing habit camouflage the weed against the container substrate. Early postemergence control of SS was evaluated with the following eight preemergence-active herbicide products; Broadstar, Casoron, Certainty, FreeHand, HGH-63, Pendulum, Tower, and V-10142. Certainty, FreeHand, Pendulum, and Tower provided greatest injury to SS in the cotyledon to one leaf stage. Tower, Pendulum, and Certainty also provided the highest injury ratings to SS in the 2 to 4 leaf stage. Data reported here show that FreeHand, Tower, Pendulum, and Certainty can provide early postemergence control of SS, however treatments are most effective when SS are treated in the C–1L stage. It is important to note that over the top herbicide applications of EC formulations and certain sulfonyl urea herbicides can cause injury to some ornamental species and grower testing is necessary prior to large scale application.

Introduction

Growth of containerized nursery crops can be significantly reduced by weeds (2). Spotted spurge (SS) (*Chamaesyce maculata* L.) is the most common summer annual broadleaf weed in container production and can be difficult to control once established due to prolific seed production (3, 6). The primary method of controlling SS is preemergence applied herbicides. However for preemergence applied herbicides to be effective, containers must be weed free prior to herbicide application (4). In the southeastern United States, it is common for growers to apply preemergent active herbicides every 8 to 10 weeks during the growing season (5). Spotted spurge seeds germinate very quickly and have no dormancy

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[2]Graduate Research Assistant, Auburn University, Dept. of Horticulture, Auburn AL 36849.

[3]Professor, Auburn University, Dept. of Horticulture, Auburn, AL 36849.

[4]Professor, Auburn University, Dept. of Agronomy and Soils, Auburn, AL 36849.

[5]IR-4 Ornamental Horticulture Manager, Rutgers University, New Brunswick, NJ 08901.

requirement, thus they often germinate between herbicide applications (6). The color and low-growing habit make SS seedlings difficult to see. As a result, small SS seedlings often escape hand-weeding efforts and are poorly controlled with most preemergence herbicides (4). These small SS seedlings must be removed either by hand or by chemical means for effective SS control. Judge et al. (5) reported that annual costs for supplemental hand weeding range from $2,389 to $5,506 per hectare ($976 to $2,228 per acre). Therefore it is important to find a preemergence-applied herbicide, which also has some degree of postemergence activity, to successfully control immature SS in container production. Judge and Neal (4) reported control of hairy bittercress (*Cardamine hirsuta*) and spotted spurge (*Chamaesyce maculata*), with herbicides Broadstar (flumioxazin), OH2 (oxyfluorfen + pendimethalin), and Snapshot TG (isoxaben + trifluralin) up to the cotyledon to one leaf stage. Studies by Altland et al. (1) indicate that small bittercress (0.5 to 3 cm) can be controlled with applications of the preemergence herbicide Gallery (isoxaben). The objective of this research was to compare new herbicides and formulations of Broadstar, Casoron, Certainty, FreeHand, HGH-63, Pendulum, Tower, and V-10142 for postemergence control of SS at 2 growth stages; cotyledon to one leaf stage (C–1L), and the two to four leaf stage (2–4L).

Materials and Methods

Four similar but separate experiments were conducted in order to evaluate herbicide efficacy on SS in the early stages of development after seed germination. These products included Broadstar 1604 0.25G (flumioxazin, Valent U.S.A. Corp., Walnut Creek, CA), Casoron 4G (dichlobenil, UniRoyal Chemical Co., Middlebury, CT), Certainty (sulfosulfuron, Mansanto Co., St. Louis, MO), FreeHand 1.75G (dimethenamid-P + pendimethalin, BASF Corporation, Research Triangle Park, NC), HGH-63 G (oxyfluorfen, Harrell's LLC, Lakeland, FL), Pendulum 3.3 EC (pendimethalin, BASF Corp., Research Triangle Park, NC), Tower 6.0 EC (dimethenamid-P, BASF Corporation, Research Triangle Park, NC), and V10142 0.5G (imazosulfuron, Valent USA Corporation, Walnut Creek, CA). The following procedures apply to all experiments: 8.9 cm (3.5 in) pots were filled with pinebark:sand (6:1 by vol) substrate that had previously been amended with 8.31 kg·m^{-3} (14 lbs·yd^{-3}) of 17-6-12 (17N-2.6P-10K) Polyon (Agrium Advanced Technologies, Sylacauga, AL) control-release fertilizer (8 to 9 month), 3.0 kg·m^{-3} (5 lb·yd^{-3}) of lime, and 0.9 kg·m^{-3} (1.5 lb·yd^{-3}) Micromax (The Scotts Co., Marysville, OH). Approximately fifty SS seeds were surface sown to each pot by hand at two separate dates resulting in SS at two different stages of growth at the time of treatment. Pots received two separate cycles of overhead irrigation daily, with each cycle supplying approximately 0.634 cm (0.25 in) water. Herbicides were applied to dry foliage and did not receive irrigation for 3 hours following treatment. Each experiment was treated outside of the greenhouse; Experiments 1 and 2 remained outside of the greenhouse for the duration of the study while Experiments 3 and 4 were placed inside the greenhouse the day after treatment. Spray applied herbicides (Tower and Pendulum) were applied with 187 liters·ha^{-1} (20 gal·A^{-1}) using a CO_2 backpack sprayer (80-04 nozzle) at 172.4 kPa (25 psi); granular herbicides (Broadstar, V-10142, Casoron and HGH-63) were applied with a hand-shaker. Pots were arranged by growth stage (C–1L or 2–4L) in a completely randomized design. Visual injury ratings (scale of 1 to 10, 1 = no injury, 10 = death) and shoot fresh weights (FW) were taken for each experiment. Pairwise comparisons were performed for each growth stage using Duncan's Multiple Range Test at $P \leq 0.05$.

Experiment 1. Postemergence SS control was tested at two different stages of growth, C–1L and 2–4L. On June 19, 2008, 8.9 cm pots (3.5 in) were filled with substrate, overseeded, and grown for 11 days until treatment, and reached the 2–4L. On June 26, 2008, additional pots were handled as previously described and overseeded six days before treatment, and reached the C–1L. On July 1, 2008, herbicides were applied to SS at each growth stage. Treatments included the following herbicides at their recommended label rate, (1×) and at twice this rate (2×): Broadstar at 0.42 and 0.84 kg ai·ha^{-1} (0.375 and 0.75 lbs ai·A^{-1}), Tower at 1.68 and 3.36 kg ai·ha^{-1} (1.5 and 3.0 lbs ai·A^{-1}) and V-10142 at 0.42 0.84 kg ai·ha^{-1} (0.375 and 0.75 lbs ai·A^{-1}). Each growth stage received six herbicide treatments with eight single pot replications per treatment. A non-treated control was included. Visual injury ratings were recorded at 14 and 21 days after treatment (DAT) and shoot fresh weights were also recorded at 21 DAT.

Experiment 2. Materials and methods were similar to Expt. 1 with the following exceptions: FreeHand was applied at 3.92 and 7.84 kg ai/A (3.5 and 7.0 lbs ai/A), and Pendulum was applied at 2.24 and 4.48 kg ai·ha^{-1} (2 and 4 lbs ai·A^{-1}). V-10142 was not included in Expt. 2. On July 31, 2008, pots were filled with substrate, overseeded, and grew 14 days before treatment and reached the 2–4L. On August 7, 2008, additional pots were filled and overseeded, growing 7 days before treatment and reached the C–1L. On August 14, 2008, each growth stage was treated with herbicides. Each growth stage contained nine treatments with six single pot replications per treatment. Visual injury ratings were taken at 10, 20, and 30 DAT. Fresh weights were taken at 30 DAT.

Experiment 3. Pots were filled with substrate and overseeded with SS seed on June 30, 2009, and grew for 22 days and reached the 2–4L. On July 9, 2009, pots were again filled and overseeded and SS growing for 18 days and reached C–1L. On July 21, 2009, pots were treated with the following herbicides; Broadstar at 0.21, 0.42, and 0.84 kg ai·ha^{-1} (0.188, 0.375, and 0.75 lbs ai·A^{-1}), Casoron at 1.1 and 2.2 kg ai·ha^{-1} (1 and 2 lbs ai·A^{-1}), Certainty at 0.1034 and 0.0385 kg ai·ha^{-1} (0.095 and 0.035 lbs ai·A^{-1}), FreeHand at 3.85 and 7.7 kg ai·ha^{-1} (3.5 and 7.0 lbs ai·A^{-1}), HGH-63 at 2.2 kg ai·ha^{-1} (2 lbs ai·A^{-1}), Pendulum at 2.2 and 4.4 kg ai·ha^{-1} (2 and 4.0 lbs ai·A^{-1}), Tower at 1.1 (2/3 label rate) and 1.68 kg ai·ha^{-1} (1 and 1.5 lbs ai·A^{-1}), and V-10142 0.5G at 4.1 and 8.2 kg ai·ha^{-1} (3.75 and 7.5 lbs ai·A^{-1}).

Experiment 4. Pots were filled with substrate and overseeded with SS on July 21, 2009, and grew for 16 days, and reached the 2–4L. On July 27, 2009, pots were again filled and overseeded and SS grew for ten days and reached C–1L. On August 6, 2009, pots were treated as in Expt. 3.

Results and Discussion

Experiment 1. Cotyledon to one leaf. At 14 DAT, Tower and V10142 provided the highest injury ratings on SS in the cotyledon stage of any herbicide treatment when applied at the 2× rate (9.1 and 7.1, respectively) (Table 1). V10142 at 1×

Table 1. Experiment 1. Spotted spurge (*Chamaesyce maculata*) injury ratings[z] and fresh weights from herbicide treatments at two growth stages.

Treatment[y]			Growth stage					
	Rate		Cotyledon to one leaf			Two to four leaf		
Herbicide	(kg ai·ha^{-1}[x])	Labeled	14 DAT[w]	21 DAT	F.W.[v]	14 DAT	21 DAT	F.W.
Broadstar	0.42	1×[u]	1.7c[t]	2.0ef	2.8abc	1.7b	2.1bc	2.1ab
Broadstar	0.84	2×	2.4c	2.1ef	3.5ab	1.7b	1.5c	3.4a
V10142	0.42	1×	6.1b	4.2cd	1.8bcd	1.9b	2.1bc	3.1a
V10142	0.84	2×	7.1ab	5.2bc	1.1cd	1.2b	2.9b	3.0ab
Tower	1.68	1×	6.2ab	4.9bc	1.0cd	5.7a	4.5a	1.8ab
Tower	3.36	2×	9.1a	8.9a	0.2d	6.6a	5.1a	1.4b
Non-treated	****	****	1.0c	1.0f	4.2a	1.0b	1.0c	3.3a

[z]Injury ratings taken on a scale of 1 to 10 (1 = no injury, 10 = death).

[y]All treatments were applied outside of greenhouse on July 1, 2008, and remained outside for the duration of the study.

[x]kg ai·ha^{-1} = kilograms of active ingredient per hectare.

[w]DAT = days after treatment.

[v]F.W. = fresh weight (grams per pot).

[u]'×' = manufacturer's label rate.

[t]Means separated using Duncan's Multiple Range Test ($\alpha = 0.05$).

and 2× rates, and Tower at the 1× rate each provided similar SS injury. Broadstar had little effect and was similar to the non-treated control. By 21 DAT, SS in the C–1L had the highest injury ratings when treated with Tower at the 2× rate (8.9). Broadstar again provided lowest injury ratings of any herbicide treatment and was similar to the non-treated control group at 21 DAT. Cotyledon to one leaf fresh weights (FW) indicate that the best control was achieved when SS was treated with both rates of Tower (reductions in FW compared to control of 76 and 96%), and both rates of V10142 (reductions of 57 and 74%, respectively). Tower is marketed as a preemergence active herbicide, and no previous work has reported the postemergence activity of dimethenamid-p.

Two to four leaf. At 14 DAT, SS exhibited almost no visual injury in any herbicide treatment when applied at the 2 –4L with the exception of Tower which provided some injury at both rates tested (Table 1). While Tower provided the highest injury ratings at 21 DAT, SS had begun to recover from Tower treatments by 21 DAT (4.5 and 5.1). This was true of almost all treatments indicating that SS was recovering from earlier injury. All herbicide treatments had similar FW to non-treated SS with the exception of of SS treated with Tower 2× which had lower FW.

Experiment 2. Cotyledon to one leaf. Tower at 1× provided excellent control throughout the study and at 2× rate had an injury rating of 10 on all dates (Table 2). Pendulum provided similar results to Tower at both rates tested, possibly due to the EC formulations of these herbicides. At 10 DAT, Broadstar at the 1× rate had little effect on SS in the C–1L (rating of 2.1), similar to results seen in Expt. 1. However, in Expt. 2 Broadstar provided excellent control at the 2× (rating of 9.0) (Table 2). This trend continued at 20 DAT, however by 30 DAT, SS began to recover (rating of 6.7). Spotted spurge in the C–1L treated with FreeHand at label rate were injured at 10 and 20 DAT (ratings of 6.3 and 7.6), but began to recover at 30 DAT (rating of 3.9). However when FreeHand was applied at the 2× rate, by 30 DAT all pots had an injury rating of 9 or higher. All treatments reduced FW compared to the non-treated except Broadstar (1×). Fresh weights showed no differences in treatments receiving Broadstar at the label rate and the non-treated control (Table 2). Fresh weights were zero in treatments including FreeHand at the 2×, Tower at both rates, and Pendulum at both rates indicating excellent control. While in Expt. 1 Broadstar at the 2× rate had FW similar to non-treated control, in Expt. 2 this treatment significantly reduced SS FW (0.8); however, the reason for this is unclear.

Two to four leaf. Tower at 2× (8.8) and Pendulum at the 2× rate (7.2) provided the highest injury ratings at 10 DAT (Table 2). Injury was also observed in spurge treated with FreeHand at 1× and 2× at 10 DAT, and ratings were similar to Tower and Pendulum at the 1× and 2× rates, respectively. At 20 DAT, the highest injury ratings were achieved with applications of Tower at the 2× rate, and both rates of Pendulum which had significantly higher injury ratings than all other treatments, with the exception of FreeHand at the 2× rate which was similar. Broadstar had little effect and had similar injury ratings to the non-treated control on all dates. Fresh weights taken at 30 DAT showed Tower at 2× (99% reduction in FW) and Pendulum at 2× (99% reduction) both provided excellent control of SS, however FreeHand (86 and 89% in 1× and 2×, respectively), and Pendulum at 1× (95%) provided statistically similar results. Tower at 1× (80% reduction) was similar to both FreeHand treatments, and Pendulum at 1×. Fresh weights also indicate Broadstar had the least effect of any herbicide, similar to results in Expt. 1.

Experiment 3. Cotyledon to one leaf. At 7 days after treatment (DAT), SS treated with Certainty (2×) had the highest injury ratings of any treatment (8.1) followed by plants treated with Pendulum (1× rate) (6.7) (Table 3). Plants treated with Broadstar (all rates), Casoron (all rates), HGH-63, V-10142 (× rate), and FreeHand (1× rate) had similar injury ratings to the nontreated control. At 14 DAT, SS treated with Certainty (both rates) along with Pendulum (1× rate) had highest in-

Table 2. Experiment 2. Spotted spurge (*Chamaesyce maculata*) injury ratings[z] and fresh weights from herbicide treatments at two growth stages.

Treatment[y]			Growth stage							
	Rate		Cotyledon to one leaf				Two to four leaf			
Herbicide	(kg ai·ha^{-1}[x])	Labeled	10 DAT[w]	20 DAT	30 DAT	F.W.[v]	10 DAT	20 DAT	30 DAT	F.W.
Broadstar	0.21	1/2×[u]	1.0i[t]	1.0h	1.0f	7.0ef	1.0e	1.0e	1.2e	18.1ab
Broadstar	0.42	1×[u]	2.1d[t]	2.0c	1.0d	5.6a	1.2d	1.3d	1.0d	6.4b
Broadstar	0.84	2×	9.0ab	9.1a	6.7b	0.8bc	2.0d	2.2d	1.0d	6.7b
FreeHand	3.92	1×	6.3c	7.6b	3.9c	1.8b	3.8c	5.7bc	5.0bc	1.7cd
FreeHand	7.84	2×	8.3b	9.7a	9.9a	0.0c	5.2c	6.8ab	6.0b	1.3cd
Tower	1.68	1×	9.3ab	9.6a	10.0a	0.0c	4.7c	4.7c	4.0c	2.5c
Tower	3.36	2×	10.0a	10.0a	10.0a	0.0c	8.8a	8.5a	8.7a	0.1d
Pendulum	2.24	1×	9.1ab	9.9a	10.0a	0.0c	4.7c	7.7a	8.0a	0.6cd
Pendulum	4.48	2×	9.7a	10.0a	10.0a	0.0c	7.2b	8.7a	8.7a	0.1d
Non-treated	****	****	1.0e	1.0c	1.0d	6.6a	1.0d	1.2d	1.0d	12.0a

[z]Injury ratings taken on a scale of 1 to 10 (1 = no injury, 10 = death).

[y]All treatments were applied outside of greenhouse on August 14, 2008, and remained outside for the duration of the study.

[x]kg ai·ha^{-1} = kilograms of active ingredient per hectare.

[w]DAT = days after treatment.

[v]F.W. = fresh weight (grams per pot).

[u]'×' = manufacturer's label rate.

[t]Means separated using Duncan's Multiple Range Test (α = 0.05).

jury ratings. By 28 DAT, SS had higher injury ratings when treated with Pendulum (both rates) than when treated with any other herbicide. Spotted spurge treated with either rate of Certainty seemed to be recovering with the 2× rate injury rating decreasing from 8.4 to 6.0 and the 1× rate decreasing from 7.9 to 3.4. Spotted spurge treated with Tower and FreeHand (1×) had also begun to recover at 28 DAT. However, SS fresh weights indicate that Certainty (both rates) Tower (both rates), Pendulum (both rates) and FreeHand (both rates) provided similar control. Spotted spurge fresh weights were

Table 3. Experiment 3. Spotted spurge (*Chamaesyce maculata*) injury ratings[z] and fresh weights from herbicide treatments at two growth stages.

Treatment[y]			Growth stage							
	Rate		Cotyledon to one leaf				Two to four leaf			
Herbicide	(kg ai·ha^{-1}[x])	Labeled	7 DAT[w]	14 DAT	28 DAT	F.W.[v]	7 DAT[w]	14 DAT	28 DAT	F.W.
Broadstar	0.21	1/2×[u]	1.0i[t]	1.0h	1.0f	7.0ef	1.0e	1.0e	1.2e	18.1ab
Broadstar	0.42	1×	1.0i	1.1gh	1.7ef	8.3de	1.0e	1.0e	1.5e	20.8ab
Broadstar	0.84	2×	1.0i	1.0h	1.1f	12.4bc	1.0e	1.0e	1.5e	14.4bcd
Casoron	1.1	1×	1.1hi	7.0bc	1.3ef	7.9def	1.0e	1.0e	1.2e	15.4bc
Casoron	2.2	2×	1.3hi	2.0fgh	1.0f	5.0fgh	1.5de	1.2e	1.0e	11.2cde
HGH-63	2.2	1×	1.7gh	1.1gh	1.0f	15.0ab	1.0e	1.2e	1.2e	22.0a
Certainty	0.0385	1×	3.9e	8.3a	3.7c	0.1i	2.0d	4.7bc	2.8d	3.1fgh
Certainty	0.134	2×	8.1a	9.3a	6.0b	0.0i	4.8b	7.3a	5.2b	1.8gh
Tower	1.1	2/3×	3.0f	5.6de	1.3ef	2.3hi	4.0c	2.0de	1.0e	14.4bcd
Tower	1.68	1×	5.9c	7.0bc	3.4cd	0.4i	4.5bc	4.5c	1.2e	8.8def
V-10142	4.1	1×	1.0i	1.0h	1.0f	10.2cd	1.0e	2.5d	1.2e	6.6efg
V-10142	8.2	1.5×	2.0g	2.4fg	1.1f	5.3fg	1.2e	2.2de	1.5e	6.7efg
Pendulum3.3EC	2.2	1×	6.7b	8.1ab	8.7a	0.0i	4.0c	5.7b	5.3b	1.6gh
Pendulum3.3EC	4.4	2×	4.9d	6.6cd	8.6a	0.0i	6.2a	8.3a	7.7a	0.1h
FreeHand	3.85	1×	1.3hi	3.1f	2.4de	3.0ghi	1.0e	1.8de	4.8bc	5.4efgh
FreeHand	7.7	2×	2.0g	4.4e	6.6b	0.4i	1.0e	1.0e	4.0c	10.8cde
Control	****	****	1.0i	1.0h	1.0f	15.4a	1.0e	1.0e	1.0e	18.5ab

[z]Injury ratings taken on a scale of 1 to 10 (1 = no injury, 10 = death).

[y]All treatments applied outside of greenhouse on July 21, 2009, and then placed inside greenhouse the following day for remainder of the study.

[x]kg ai·ha^{-1} = kilograms of active ingredient per hectare.

[w]DAT = days after treatment.

[v]F.W. = fresh weight (grams per pot).

[u]'×' = manufacturer's label rate.

[t]Means separated using Duncan's Multiple Range Test (α = 0.05).

reduced by 97% with Certainty (both rates) and Pendulum (both rates). HGH-63 had the highest fresh weights of any herbicide treatment and was similar to the nontreated SS.

Two to four leaf. At 7 DAT, SS treated with Pendulum (2×) had more injury than when treated with any other herbicide, followed by Certainty (2×). Tower (both rates) and Pendulum (1× rate) also resulted in significant SS injury. Broadstar, Casoron, HGH-63, V-10142, and FreeHand treatments (all rates) had injury ratings similar to the nontreated control. At 14 DAT SS injury was again highest in plants treated with Pendulum (2×), however plants treated with Certainty (2×) had similar injury ratings. By 28 DAT, SS treated with Pendulum (2×) had higher injury ratings than when treated with any other treatment. Broadstar (all rates), Casoron (both rates), HGH-63, Tower (both rates), and V-10142 (both rates), caused little or no injury and SS treated with these herbicides had similar injury ratings to the nontreated control. Spotted spurge treated with FreeHand exhibited injury at both rates (4.8 and 4.0). Fresh weights indicate Pendulum (2×) treatment reduced SS FW by 99%. Other treatments causing FW reductions were Certainty (2×) (90%), Certainty (1× rate) (85%), Pendulum (1× rate) (91%) and FreeHand (1× rate) (70%).

Experiment 4. Cotyledon to one leaf. At 7 DAT, SS treated with Pendulum (2×) had higher injury ratings than any other treatment, followed by Pendulum (1× rate), and Tower (both rates) (Table 4). V-10142 (both rates) and FreeHand (1× rate) caused little SS injury and SS had injury ratings similar to nontreated plants. Pendulum (both rates) and Certainty (2×) caused the greatest injury at 14 DAT. Tower also provided high injury ratings at 1× (rating of 7.7) and 2/3× rate (rating of 7.9), while Broadstar (1/2×), Casoron (both rates) HGH-63, and V-10142 (both rates) caused little or no SS injury. By 28 DAT, SS treated with Pendulum (both rates) along with FreeHand (2×) had higher injury ratings than any other treatment; However FreeHand (1× rate) was similar to Pendulum (1× rate) and FreeHand (2× rate). Spotted spurge had high injury ratings when treated with Certainty or Tower earlier in the experiment; however as in Expt. 3, SS began to recover by 28 DAT. Broadstar (1/2×), Casoron (both rates), HGH-63, and V-10142 provided little control throughout the experiment. Even though SS had begun to recover (no injury symptoms), SS fresh weights were reduced significantly with Certainty (95 and 99% with 1× and 2× rates, respectively), Tower (99 and 99% with 2/3× and 1× rates, respectively), Pendulum (both rates 100%), and FreeHand (99 and 100% with 1× and 2× rates, respectively). All herbicide treated SS had lower FW than nontreated plants; however Broadstar, Casoron, HGH-63, and V-10142 only provided marginal control.

Two to four leaf. As in Expt. 3, at 7 DAT SS treated with Pendulum (2×) had higher injury ratings than when treated with any other herbicide (Table 4). Pendulum (1×) and Tower (2/3×) had the next highest injury ratings, while Broadstar (1× and 1/2×), Casoron (both rates), HGH-63, V-10142 (both rates), and FreeHand (both rates) caused little injury and SS treated with these herbicides had similar injury ratings to nontreated plants. At 14 DAT, both Pendulum rates caused the greatest (ratings of 6.6 and 6.1). Spotted spurge treated with Broadstar (all rates), Casoron (both rates), HGH-63, V-10142, and FreeHand (both rates) had similar injury rat-

Table 4. Experiment 4. Spotted spurge (*Chamaesyce maculata*) injury ratings[z] and fresh weights from herbicide treatments at two growth stages.

Treatment[y]			Growth stage							
	Rate		Cotyledon to one leaf				Two to four leaf			
Herbicide	(kg ai·ha^{-1}[x])	Labeled	7 DAT[w]	14 DAT	28 DAT	F.W.[v]	7 DAT[w]	14 DAT	28 DAT	F.W.
Broadstar	0.21	1/2×[u]	2.3ef[t]	1.9de	1.7hi	9.4de	1.1g	1.1d	1.3f	16.0ab
Broadstar	0.42	1×	2.0f	2.4d	3.0gh	5.0fg	1.1g	1.1d	1.3f	14.9ab
Broadstar	0.84	2×	2.4e	5.1c	4.1fg	1.7gh	2.0f	1.1d	1.5ef	14.1ab
Casoron	1.1	1×	2.0f	1.0e	1.0i	13.6bc	1.3g	1.4d	1.4f	11.1bc
Casoron	2.2	2×	2.0f	1.8de	1.4i	7.5ef	1.0g	1.4d	1.0f	14.1ab
HGH-63	2.2	1×	2.6e	1.0e	1.0i	17.2b	1.0g	1.0d	1.0f	13.8ab
Certainty	0.0385	1×	4.1d	6.4c	4.3fg	1.1h	3.0e	2.5bc	2.4cde	6.7cd
Certainty	0.134	2×	5.0c	8.0ab	6.7cd	0.1h	4.0d	2.9b	3.1c	4.2def
Tower	1.1	2/3×	6.9b	7.9b	5.9de	0.3h	5.6bc	3.1b	1.8def	7.7cd
Tower	1.68	1×	7.0b	7.7b	4.7ef	0.2h	5.5c	2.9b	1.1f	7.1cd
V-10142	4.1	1×	1.0g	1.0e	1.0i	13.9bc	1.1g	1.3d	1.0f	11.4bc
V-10142	8.2	1.5×	1.0g	1.3de	1.1i	11.4cd	1.0g	1.0d	1.1f	12.7ab
Pendulum3.3EC	2.2	1×	7.0b	8.1ab	8.6ab	0.0h	6.0b	6.1a	5.4b	1.3ef
Pendulum3.3EC	4.4	2×	8.0a	9.3a	9.6a	0.0h	7.4a	6.6a	7.1a	0.4f
FreeHand	3.85	1×	1.3g	5.4c	7.6bc	0.2h	1.0g	1.0d	2.6cd	5.5de
FreeHand	7.7	2×	2.0f	6.1c	8.9ab	0.0h	1.0g	1.9cd	2.8c	4.4def
Control	****	****	1.0g	1.0e	1.0i	21.4a	1.0g	1.0d	1.0f	17.3a

[z]Injury ratings taken on a scale of 1 to 10 (1 = no injury, 10 = death).

[y]All treatments applied outside of greenhouse on August 6, 2009, and then placed inside greenhouse the following day for remainder of the study.

[x]kg ai·ha^{-1} = kilograms of active ingredient per hectare.

[w]DAT = days after treatment.

[v]F.W. = fresh weight (grams per pot).

[u]'×' = manufacturer's label rate.

[t]Means separated using Duncan's Multiple Range Test ($\alpha = 0.05$).

ings to nontreated SS. At 28 DAT, SS treated with Broadstar (all rates), Casoron (both rates), HGH-63, Tower (both rates), and V-10142 (both rates) again had similar injury ratings to nontreated plants. Pendulum (2×) had the lowest mean fresh weight, however SS treated with Pendulum (1×), FreeHand (2×) and Certainty (2×) had similar FW.

In summary, Tower at both 1× and 2×, V10142 at 2×, FreeHand at 1× and 2×, Pendulum at the 1 and 2×, and Certainty (both 1× and 2×) provided postemergence control of SS when applied in C–1L. Tower, Pendulum, and Certainty consistently provided high SS injury ratings at both rates tested when applied to SS in the 2–4L as well. In some cases SS had lower injury ratings when treated with Tower in Expts. 3 and 4, however Tower was applied at lower rates (2/3× and 1×) in Expts. 3 and 4 due to the excellent control observed when applied at the 1× and 2× rates in Expts. 1 and 2.

Broadstar provided the lowest SS injury ratings (all tested rates) at any stage of growth. However, flumioxazin, the active ingredient in Broadstar has been previously reported as having excellent postemergence SS control (≥ 99%) when applied to SS in the C–1L (5). However, Broadstar used in these studies was the new V1604 formulation, which has been formulated to reduce potential crop injury when applied over the top of container ornamentals. While this new formulation may be safer for use on ornamentals, a comparison of results from this study with that of Judge and Neal (5) indicate a potential reduction in postemergence weed control.

Applications of Certainty, FreeHand, Pendulum, Tower, and V-10142 to control SS after weed emergence could reduce labor costs from hand weeding and also provide preemergence activity. If small SS plants are present before or during the application of pre-emergence active herbicides, the herbicides identified in this research could provide some degree of postemergence activity depending on the growth stage of the SS. When applying emulsifiable concentrate (EC) herbicides (Tower and Pendulum 3.3 EC) or sulfonyl urea herbicides (Certainty) over the top, there may be some potential for injury on certain ornamental species. Prior to over the top applications of these herbicides, grower testing is necessary to ensure crop safety before making a broad spectrum application. It is also important to note that many of the herbicides evaluated provided excellent SS at the 1× rate in the C–1L, in some cases once spurge reached the 2–4L similar control was only achieved at the 2×, which is outside of the manufacturer's labeled rate, and growers would assume liability in the case of crop injury.

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