Phytotoxicity of Three Sulfonyl Urea Herbicides on Twelve Ornamental Plant Species[1]

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Abstract

Plants of ten woody shrub species, euonymus, winter jasmine, spirea, golden privet, crape myrtle, forsythia, hydrangea, redbud, viburnum, and weigela, and two bedding plant species, marigold (annual) and dianthus (perennial), were sprayed over the top with sulfosulfuron, trifloxysulfuron-sodium, or halosulfuron-methyl at two times the label rate or sulfosulfuron was sprayed over the top with the label rate and then sprayed with the label rate 30 days later to determine phytotoxic effects of the herbicides. All of the sulfonyl urea herbicides tested were safe to use on euonymus, but none should be used on redbud, weigela, spirea, or crape myrtle. Trifloxysulfuron-sodium typically caused more phytotoxicity on all species tested except euonymus, while halosulfuron-methyl was least likely. Sulfosulfuron also should not be used on privet, hydrangea, or winter jasmine.

Index words: halosulfuron-methyl, trifloxysulfuron-sodium, sulfosulfuron, euonymus, marigold, winter jasmine, spirea, golden privet, crape myrtle, viburnum, forsythia, hydrangea, dianthus, redbud, weigela.

Chemicals used in this study: Sedgehammer [(halosulfuron-methyl) (3-chloro-5-[[[[(4,6-dimethoxy-2-pyrimidinyl)amino]carbonyl] amino]sulfonyl]-1-methyl-1*H*-pyrazole-4-carboxylic acid)], Certainty [(sulfosulfuron) (N-[[(4,6-dimethoxy-2-pyrimidinyl)amino] carbonyl]-2-(ethylsulfonyl)imidazol[1,2-a]pyridine-3-sulfonamide)], and Monument [(trifloxysulfuron-sodium) (N-[[(4,6-dimethoxy-2-pyrimidinyl)amino]carbonyl]-3-(2,2,2-trifluoroethoxy)-2-pyridinesulfonamide)].

Species used in this study: euonymus (*Euonymus fortunei* (Turcz.) Hand.-Mazz. 'Moonshadow'); marigold (*Tagetes erecta* L. 'Inca II Gold'); winter jasmine (*Jasminium nudiflorum* Lindl.); spirea (*Spiraea × bumalda* Burv. 'Goldmound'); golden privet (*Ligustrum × vicaryi* Rehder); Rhapsody in Pink® crape myrtle (*Lagerstroemia indica* L. 'Whit VIII'); viburnum (*Viburnum lantana* L. 'Mohican'); forsythia (*Forsythia × intermedia* Zab. 'Lynwood Gold'); hydrangea (*Hydrangea macrophylla* (Thunb.) Ser. 'Penny Mac'); wine dianthus (*Dianthus hybrida* L. 'Raspberry Surprise'); redbud (*Cersis canadensis* L.); weigela (*Weigela florida* (Bunge) A. DC.

Significance to the Nursery Industry

A successful weed control program can help nursery crop growers produce better quality crops by eliminating weed competition and potential allelopathic effects of weeds. The sulfonyl urea herbicides have been effective at eliminating grassy weeds and nutsedge from various crops, but limited information is available on potential phytotoxic affects of these herbicides on ornamental species. This research shows that trifloxysulfuron-sodium generally caused the greatest damage ratings and halosulfuron-methyl generally caused the lowest damage ratings of the herbicides tested on most species. Sulfosulfuron was generally intermediate in damage and damage was species dependent. For all of the herbicides, when damage occurred, it was generally most prominent four or eight weeks after application, then decreased.

Introduction

Controlling weeds in nursery crops is necessary to avoid competition and potential allelopathic effects on crop plants. Weed control in nurseries is a challenge since a wide variety of plant species with different cultural needs and susceptibilities to herbicide damage are often grown in a relatively small space. An added challenge is that many herbicide companies consider ornamentals to be a small portion of their business, and do not expect an adequate return of testing expenses to include ornamentals on their labels.

Carefully selected sulfonylurea herbicides are effective at eliminating several weedy grass species from creeping bentgrass (*Agrostis stolonifera* L.), Kentucky bluegrass (*Poa pratensis* L.), bermudagrass (*Cynodon dactylon* L.), and zoysiagrass (*Zoysiagrass japonica* Steud.) (3). Halosulfuron-methyl was effective at controlling yellow nutsedge (*Cyperus esculentus* L.) and purple nutsedge (*Cyperus rotundus* L.) in nursery crops, but control depended somewhat on the adjuvant used (5, 6).

Halosulfuron-methyl has been tested for phytotoxicity on several ornamental species. Bachman et al. (1) noted that halosulfuron-methyl caused foliar damage to crape myrtle (*Lagerstroemia indica* L. 'Carolina Beauty'), cotoneaster (*Cotoneaster dammeri* C.K. Schneid. 'Coral Beauty'), and dwarf Japanese juniper (*Juniperus chinensis procumbens* Endl. 'Nana'). It also reduced the growth of cotoneaster and Hetzi blue juniper (*Juniperus chinensis* L. 'Hetzi Glauca'); however, Parsons (*Juniperus chinensis* L. 'Parsoni') and Blue Pacific (*Juniperus confert* Parl. 'Blue Pacific') junipers were not affected by halosulfuron-methyl.

McDaniel et al. (5) investigated the effect of halosulfuron-methyl mixed with selected adjuvants for phytotoxicity to ornamentals. Halosulfuron-methyl in combination with any adjuvant tested injured Japanese holly (*Ilex crenata* Thunb 'Bennett's Compact'), forsythia (*Forsythia × intermedia* Zab. 'Lynwood Gold'), green liriope (*Liriope muscari* Bailey 'Big Blue'), and weigela (*Weigela florida* Bunge 'Pink Lady'), but not 'Blue Girl' holly (*Ilex × meserveae* S.Y. Hu 'Blue Girl'). Halosulfuron-methyl combined with the adjuvant Scoil® produced moderate phytotoxicity on forsythia and weigela and reduced growth of all landscape plants. Similarly halosulfuron-methyl combined with the adjuvant Action '99'

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caused severe phytotoxicity to weigela and reduced growth of all plants tested. Halosulfuron-methyl plus the adjuvant Agri-Dex resulted in moderate to severe growth reduction to all plants with severe marginal necrosis of foliage on forsythia and weigela. Halosulfuron-methyl with the adjuvant Sun-It II resulted in less growth reduction and fewer phytotoxic symptoms of the test species compared to other halosulfuron-methyl/adjuvant combinations. Halosulfuron-methyl combined with various adjuvants was also tested for phytoxicity on liriope (*Liriope muscari* (Decne.) Bailey 'Big Blue') and daylily (*Hemerocallis* sp. L. 'Stella d'Oro') (6). Growth of liriope treated with halosulfuron-methyl combined with either adjuvant, Scoil® or Sun-It II®, was not inhibited. Regardless of the rate of halosulfuron-methyl applied or adjuvant, intial foliar chlorosis was observed in both daylily and liriope, but liriope in most treatments recovered normal foliage by eight weeks after treatment.

Sulfonyl urea herbicides inhibit acetolactate synthase in plants (4). This enzyme is not present in mammals, so this family of herbicides presents a low risk to human health (7). Advantages of using the sulfonyl urea herbicides have been cited as very low use rates, excellent selectivity, and low mammalian toxicity (2).

A search of the literature revealed no information regarding possible phytotoxic affects of the sulfonyl urea herbicides trifloxysulfuron-sodium or sulfosulfuron on ornamentals. The objective of this study was to determine whether application of trifloxysulfuron-sodium, sulfosulfuron, or halosulfuron-methyl over the top of plants caused phytoxicity on several ornamental species.

Materials and Methods

2008. Commercially-grown, ready-for-sale plants in #1 containers were used for all species in this study except marigold, dianthus, and redbud. Marigold and dianthus were obtained as commercially produced plugs and transplanted into #SP4 pots on February 25 and 27, respectively, and then grown in a heated greenhouse. In mid-April, marigold and dianthus plants were transplanted into #3 containers containing Metromix 702 (Sungro, Vancouver, British Columbia, Canada), and maintained in a corrugated polycarbonate-covered greenhouse (Oklahoma State University Research Greenhouse, Stillwater, OK) with an average day/night air temperature of 30/15C (86/59F) and a maximum photosynthetic photon flux (PPF) of 1500 $\mu mol \cdot m^{-2} \cdot sec^{-1}$ until early June. While in the greenhouse, plants were irrigated with 1.9 mm internal diameter polyethylene microtubes and lead-weighted on/off emitters daily as needed and fertilized at each irrigation five days a week with 100 $mg \cdot liter^{-1}$ (0.01 $oz \cdot gal^{-1}$) N from 20N-8.7P-16.6K (20N-20P_2O_5-20K_2O Jack's Professional, Allentown, PA). Plants received soluble trace elements (STEM, Jacks Professional) as a substrate drench at 100 $mg \cdot liter^{-1}$ (0.01 $oz \cdot gal^{-1}$) every two weeks. The growth substrate for redbud trees consisted of pine bark:peat moss:sand (3:1:1 by vol) amended with 4.3 $kg \cdot m^{-3}$ (7.2 $lb \cdot yd^{-3}$) N as 17N-3.6P-10K (17-7-12) controlled release fertilizer (Osmocote, The Scotts Co., Marysville, OH), 0.9 $kg \cdot m^{-3}$ (1.5 $lb \cdot yd^{-3}$) micronutrients (Micromax, The Scotts Co.) and 1.8 $kg \cdot m^{-3}$ (3.0 $lb \cdot yd^{-3}$) dolomite. Bareroot redbud trees were transplanted into #3 containers in early May.

Plants of all species were sprayed with the following herbicides and rates: a) control (tap water), b) sulfosulfuron at 87.7 $g \cdot ha^{-1}$ (1.2 $oz \cdot A^{-1}$) (label rate), c) sulfosulfuron at 173.0 $g \cdot ha^{-1}$ (2.4 $oz \cdot A^{-1}$) (2 times label rate), d) halosulfuron-methyl at 182.4 $g \cdot ha^{-1}$ (2.6 $oz \cdot A^{-1}$) (2 times label rate), or e) trifloxysulfuron-sodium at 74.1 $g \cdot ha^{-1}$ (1.0 $oz \cdot A^{-1}$) (2 times label rate). Thirty days after the first application, the plants initially sprayed with the sulfosulfuron at 87.7 $g \cdot ha^{-1}$ (1.2 $oz \cdot A^{-1}$) (label rate) were sprayed again with the same rate. Nonionic surfactant (Surf-King Plus Spreader-Activator with Buffering Agents, Estes, Wichita Falls, TX) was included in the spray solution for all treatments (including the control) at 0.25% by volume.

Plants were sprayed June 22 between 1200 and 1300 HR. The air temperature at the time of spraying was 33C (91.4F) and wind was calm. The plants were placed in full sun for herbicide application, allowed to dry after application, and then moved into a shade house at The Botanic Garden at Oklahoma State University (Stillwater, OK) with a maximum photosynthetic photon flux of 1214 $\mu mol \cdot m^{-2} \cdot sec^{-1}$. Beginning 24 hr after herbicide application, plants were watered daily with overhead sprinkler irrigation (about 2.5 $cm \cdot day^{-1}$, 1 $in \cdot day^{-1}$) throughout the growing season.

Plants were rated for phytotoxicity symptoms including foliar or stem damage 2, 4, 8, and 12 weeks after herbicide application. The rating scale was from 0 to 100 with 0 indicating no injury and 100 indicating a dead plant. Plant heights and widths (measured at the widest point and perpendicular to the widest point) were measured when the study was initiated and at termination (12 weeks after herbicide application).

2009. The 2008 study was repeated in 2009 excluding dianthus, and redbud trees were commercially grown in #5 containers. Plants were sprayed June 9 at about 0900 HR. The temperature at the time of spraying was 23.9C (75.0F) and the wind was calm.

Statistics. In both years, a completely randomized design within plant species was used. Each herbicide treatment was replicated six times for all species except redbud was replicated five times in 2009. Data were analyzed using the GLM procedure in SAS 9.1 (SAS Institute, Cary, NC). For significant herbicide by time after treatment interactions, trend analyses were performed on plant rating data to determine trends in ratings over time within species and herbicide. Mean separations between herbicides were performed using a protected LSD.

Results and Discussion

2008. No damage appeared on euonymus with any herbicide tested, so no herbicide by time after treatment interaction existed for damage ratings (data not presented). Damage ratings on euonymus did not differ among the herbicides, and no trends occurred with time after application for plant ratings. Likewise, no differences in herbicides occurred in plant height or width growth of euonymus.

All herbicides tested and both rates of sulfosulfuron resulted in a curvilinear relationship between damage rating and weeks after treatment for weigela and redbud (Table 1). Ratings indicated phytotoxic symptom severity was greatest four weeks after application on both species with all herbicide treatments, except severity on weigela was greatest eight weeks after application using two single rate sulfosulfuron applications. Trifloxysulfuron-sodium damage ratings on weigela and redbud four weeks after application were higher than those of any other herbicide treatment on that date, but

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Table 1. **Plant damage rating at 2, 4, 8, and 12 weeks after treatment of several plant species sprayed in 2008 with sulfosulfuron at 87.7 g·ha^{-1} (1.2 oz·A^{-1}) (label rate, 1×) with a repeat spray 30 days later (1× + 1×), sulfosulfuron at 173.0 g·ha^{-1} (2.4 oz·A^{-1}) (twice the label rate, 2×), trifloxysulfuron-sodium at 74.1 g·ha^{-1} (1.0 oz·A^{-1}) (twice the label rate, 2×), halosulfuron-methyl at 182.4 g·ha^{-1} (2.6 oz·A^{-1}) (2 times label rate, 2×), or tap water (control). All treatments included nonionic surfactant at 0.25% by volume. n = 6.**

	Plant damage rating[z]				
Weeks after treatment	**Sulfosulfuron (1× + 1×)**	**Sulfosulfuron (2×)**	**Trofloxysulfuron-sodium**	**Halosulfuron-methyl**	**Control**
			Weigela		
2	2	5	5	5	0
4	27	27	48	31	0
8	56	24	38	4	0
12	10	10	8	0	0
Linear	**	NS	**	**	NS
Quadratic	**	**	**	**	NS
Cubic	**	**	**	**	NS
			Redbud		
2	5	5	4	0	0
4	19	20	32	6	0
8	0	0	0	0	0
12	0	0	0	0	0
Linear	**	**	**	NS	NS
Quadratic	NS	NS	**	NS	NS
Cubic	**	**	**	*	NS
			Privet		
2	1	0	2	0	0
4	13	23	31	12	19
8	26	4	35	0	24
12	0	0	0	0	0
Linear	NS	*	NS	NS	NS
Quadratic	**	**	**	NS	**
Cubic	NS	**	NS	NS	NS
			Hydrangea		
2	4	5	4	0	0
4	45	51	48	0	0
8	53	40	30	0	0
12	9	1	6	0	0
Linear	NS	**	**	NS	NS
Quadratic	**	**	**	NS	NS
Cubic	*	**	**	NS	NS
			Winter jasmine		
2	0	1	5	0	0
4	9	16	16	6	0
8	24	50	43	0	2
12	1	12	4	1	0
Linear	NS	**	NS	NS	NS
Quadratic	**	**	**	NS	NS
Cubic	*	**	**	NS	NS
			Spirea		
2	5	6	20	0	0
4	5	6	20	0	0
8	7	4	9	6	0
12	2	1	6	6	0
Linear	NS	NS	**	*	NS
Quadratic	NS	NS	NS	NS	NS
Cubic	NS	NS	NS	NS	NS
			Crape myrtle		
2	0	0	0	0	0
4	0	0	32	0	0
8	0	6	6	18	0
12	0	0	0	4	0
Linear	NS	NS	**	NS	NS
Quadratic	NS	*	**	NS	NS
Cubic	NS	NS	**	NS	NS

…Continued

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Table 1. Continued…

Weeks after treatment	Plant damage rating[z] Sulfosulfuron (1× + 1×)	Sulfosulfuron (2×)	Trofloxysulfuron-sodium	Halosulfuron-methyl	Control
			Forsythia		
2	0	0	0	0	0
4	0	0	30	0	0
8	0	0	0	0	0
12	0	0	0	0	0
Linear	NS	NS	***	NS	NS
Quadratic	NS	NS	***	NS	NS
Cubic	NS	NS	***	NS	NS
			Viburnum		
2	0	0	5	0	0
4	0	0	17	0	0
8	0	0	10	0	0
12	0	0	0	0	0
Linear	NS	NS	**	NS	NS
Quadratic	NS	NS	**	NS	NS
Cubic	NS	NS	*	NS	NS
			Marigold		
2	0	1	6	0	0
4	0	0	0	0	0
8	0	0	0	0	0
12	0	0	0	0	0
Linear	NS	NS	**	NS	NS
Quadratic	NS	NS	**	NS	NS
Cubic	NS	NS	**	NS	NS
			Dianthus		
2	4	7	7	2	0
4	7	12	11	6	0
8	62	15	2	7	0
12	20	0	23	5	0
Linear	**	NS	NS	NS	NS
Quadratic	**	NS	NS	NS	NS
Cubic	**	NS	NS	NS	NS

[z]Ratings were on a scale of 0 to 100 with 0 being a plant with no damage and 100 being a dead plant.

[NS, *, **]Not significant or significant at $P \leq 0.05$ or 0.01, respectively.

damage ratings were greatest on weigela eight weeks after treatment with the two 1× applications of sulfosulfuron. Redbud growth was not affected by any herbicide treatment (data not presented), but weigela treated with either sulfosulfuron treatment or trifloxysulfuron-sodium grew less in height and width than control plants or plants treated with halosulfuron-methyl (Table 2).

Both sulfosulfuron treatments and trifloxysulfuron-sodium application resulted in curvilinear relationships between damage ratings and weeks after treatment for privet, hydrangea and winter jasmine (Table 1). The trifloxysulfuron-methyl or two 1× applications of sulfosulfuron resulted in the greatest damage ratings eight weeks after treatment of privet, but the greatest damage rating for plants receiving 2× sulfosulfuron occurred four weeks after treatment. A curvilinear relationship between damage ratings and time occurred in the control treatment in privet. This is attributed to a mixing error with the adjuvant that damaged the foliage of plants in this species. Growth was not inhibited on privet with any herbicide application (data not presented).

The greatest damage ratings on hydrangea was eight weeks after treatment for the two 1× applications of sulfosulfuron, but four weeks after application for the single 2× application of sulfosulfuron or trifloxysulfuron-sodium (Table 1). Hydrangea plants receiving either sulfosulfuron treatment grew less in height than those in any other treatment, while hydrangeas receiving either sulfosulfuron treatment or trifloxysulfuron-sodium grew less in width than those receiving halosulfuron-methyl or the control plants (Table 2).

The greatest damage ratings on winter jasmine occurred eight weeks after treatment for both sulfosulfuron treatments and trifloxysulfuron-sodium. The 2× rate of sulfosulfuron had the greatest damage ratings among the herbicide treatments. Winter jasmine growth was not affected by any herbicide treatment (data not presented).

Application of trifloxysulfuron-sodium resulted in a linear decrease while halosulfuron-methyl resulted in a linear increase in damage ratings on spirea with time after application (Table 1). Trifloxysulfuron-sodium resulted in the highest damage ratings among the herbicides tested and those high ratings occurred two and four weeks after application, gradually decreasing with time. Damage ratings of plants sprayed with halosulfuron-methyl were low and unlikely to be noticed by consumers. Plant growth in height and width were not affected by herbicide treatments (data not presented).

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Table 2. **Plant growth in height and width of several plant species treated with sulfosulfuron at 87.7 g·ha^{-1} (1.2 oz·A^{-1}) (label rate, 1×) with a repeat spray 30 days later (1× + 1×), sulfosulfuron at 173.0 g·ha^{-1} (2.4 oz·A^{-1}) (twice the label rate, 2×), trifloxysulfuron-sodium at 74.1 g·ha^{-1} (1.0 oz·A^{-1}) (twice the label rate, 2×), halosulfuron-methyl at 182.4 g·ha^{-1} (2.6 oz·A^{-1}) (2 times label rate, 2×), or tap water (control) in 2008 and 2009. All treatments included nonionic surfactant at 0.25% by volume. n = 6 for all species except redbud in 2009 in which n = 5.**

		Plant growth (cm)	
Species	Herbicide	Height	Width
	2008		
Weigela	Sulfosulfuron (1× + 1×)	20.2b[z]	10.6b
	Sulfosulfuron (2×)	24.4b	11.5b
	Trifloxysulfuron-sodium	19.6b	12.4b
	Halosulfuron-methyl	45.6a	28.1a
	Control	52.6a	25.1a
Hydrangea	Sulfosulfuron (1× + 1×)	6.4b	12.2cd
	Sulfosulfuron (2×)	4.2b	10.3d
	Trifloxysulfuron-sodium	17.2a	17.6c
	Halosulfuron-methyl	14.4a	33.9a
	Control	17.6a	26.9b
Forsythia	Sulfosulfuron (1× + 1×)	78.0ab[z]	85.2ab
	Sulfosulfuron (2×)	73.2b	76.4b
	Trifloxysulfuron-sodium	59.2c	38.9d
	Halosulfuron-methyl	82.6ab	50.4c
	Control	89.4a	92.0a
Viburnum	Sulfosulfuron (1× + 1×)	3.2b	4.3a
	Sulfosulfuron (2×)	3.4b	3.6a
	Trifloxysulfuron-sodium	12.8a	0.0a
	Halosulfuron-methyl	0.8b	4.6a
	Control	13.4a	5.7a
	2009		
Crape myrtle	Sulfosulfuron (1× + 1×)	14.5ab	0.2a
	Sulfosulfuron (2×)	11.8b	5.7a
	Trifloxysulfuron-sodium	4.5c	2.4a
	Halosulfuron-methyl	16.5a	7.4a
	Control	19.3a	2.8a
Hydrangea	Sulfosulfuron (1× + 1×)	2.0a	–4.1d
	Sulfosulfuron (2×)	10.3a	3.5bc
	Trifloxysulfuron-sodium	4.3a	3.8b
	Halosulfuron-methyl	7.7a	0.4c
	Control	9.7a	6.2a
Weigela	Sulfosulfuron (1× + 1×)	–2.2c	0.0c
	Sulfosulfuron (2×)	6.5b	1.8c
	Trifloxysulfuron-sodium	–10.5d	–11.2d
	Halosulfuron-methyl	7.3ab	10.2b
	Control	9.8a	16.1a
Forsythia	Sulfosulfuron (1× + 1×)	56.7a	135.2a
	Sulfosulfuron (2×)	61.5a	112.0ab
	Trifloxysulfuron-sodium	31.8a	77.8c
	Halosulfuron-methyl	50.3a	105.5b
	Control	44.3a	111.3b
Redbud	Sulfosulfuron (1× + 1×)	10.4a	19.4a
	Sulfosulfuron (2×)	5.4a	13.8a
	Trifloxysulfuron-sodium	–26.6b	23.7a
	Halosulfuron-methyl	7.8a	21.6a
	Control	3.0a	22.1a
Marigold	Sulfosulfuron (1× + 1×)	5.4a	21.4a
	Sulfosulfuron (2×)	9.2a	20.3a
	Trifloxysulfuron-sodium	5.3a	11.9c
	Halosulfuron-methyl	7.2a	17.0b
	Control	9.8a	16.5b

[z]Means within cultivar and column followed by the same letter do not significantly differ. Means separation by protected LSD.

The 2× sulfosulfuron or trifloxysulfuron-sodium treatments resulted in a curvilinear relationship between damage rating and time after application on crape myrtle (Table 1). While statistically sulfosulfuron resulted in greater damage eight weeks after treatment compared to the other weeks, that damage was low and would likely not be considered horticulturally significant. In contrast, trifloxysulfuron-sodium resulted in the greatest damage four weeks after application, then damage declined with time. Growth of crape myrtle was not affected by any herbicide treatment (data not presented).

Application of trifloxysulfuron-sodium caused a curvilinear relationship between damage ratings and weeks after treatment on forsythia, viburnum, and marigold (Table 1). The highest damage ratings occurred four weeks after application on forsythia and viburnum but two weeks after application on marigold. The damage on marigold was low and not likely horticulturally significant. Forsythia plants receiving trifloxysulfuron-sodium grew less in height and width than those in any other treatment (Table 2). Viburnums receiving either application of sulfosulfuron or halosulfuron-methyl grew less in height than plants receiving trifloxysulfuron-sodium or control plants, but width of viburnums was not affected by any herbicide treatment. Marigold plant growth was not affected by any herbicide treatment (data not presented).

A curvilinear relationship existed between damage ratings with sulfosulfuron applied in two 1× applications and time after application on dianthus such that the greatest rating occurred eight weeks after application (Table 1). None of the herbicides resulted in reduced growth of dianthus (data not presented).

2009. No herbicide by time interaction occurred for damage ratings on privet or spirea. Trifloxysulfuron-sodium and halosulfuron-methyl resulted in greater damage ratings compared to either sulfosulfuron treatment or the control plants of privet (Table 3). A linear relationship occurred between damage ratings and time on privet. Damage ratings in all herbicide treatments on privet were very low and not likely horticulturally significant. Plant growth of privet in height and width were not affected by herbicide treatments (data not presented).

On spirea, plants in all herbicide treatments had higher damage ratings than control plants, and a curvilinear relationship between time and damage ratings existed such that damage ratings were greatest four weeks after application (Table 3). No difference in spirea plant growth in height or width occurred (data not presented).

Plant damage ratings were curvilinearly related to time after application of all herbicide treatments on crape myrtle (Table 4). The highest ratings for trifloxysulfuron-sodium-treated plants occurred four weeks after treatment while the highest ratings in all other treatments (including control plants) occurred eight weeks after treatment. Plants receiving trifloxysulfuron-sodium had higher damage ratings than those in any other treatment two weeks after treatment. Crape myrtle plants treated with halosulfuron-methyl and control plants grew more in height than those treated with the 2× rate of sulfosulfuron, while plants treated with trifloxysulfuron-sodium grew the least in height among the treatments (Table 2). Crape myrtle plants were very large in relation to the pot size in 2009 and might have benefited from more irrigation

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Table 3. **Plant damage ratings of privet and spirea sprayed in 2009 with sulfosulfuron at 87.7 g·ha⁻¹ (1.2 oz·A⁻¹) (label rate, 1×) with a repeat spray 30 days later (1× + 1×), sulfosulfuron at 173.0 g·ha⁻¹ (2.4 oz·A⁻¹) (twice the label rate, 2×), trifloxysulfuron-sodium at 74.1 g·ha⁻¹ (1.0 oz·A⁻¹) (twice the label rate, 2×), halosulfuron-methyl at 182.4 g·ha⁻¹ (2.6 oz·A⁻¹) (2 times label rate, 2×), or tap water (control) at 2, 4, 8, and 12 weeks after treatment. All treatments included nonionic surfactant at 0.25% by volume. Damage ratings were on a scale of 0 to 100 with 0 being no damage and 100 being a dead plant. n = 24 for herbicide main effect and n = 30 for weeks after treatment main effect.**

Treatment	Privet	Spirea
	Herbicide main effect	
Control	0a[z]	0a
Sulfosulfuron (1× + 1×)	2a	12d
Sulfosulfuron (2×)	1a	3b
Trifloxysulfuron (2×)	5b	8c
Halosulfuron (2×)	5b	7c
	Weeks after treatment main effect	
2	2	2
4	5	11
8	2	8
12	0	2
Linear	*	NS
Quadratic	NS	**
Cubic	NS	*

[z]Means followed by the same letter do not significantly differ at $P \leq 0.05$ by protected LSD.

[NS, *, **]Not significant or significant at $P \leq 0.05$ or 0.01, respectively.

than other plants in the study, which would account for the damage ratings on the control plants eight and 12 weeks after treatment.

Damage ratings of winter jasmine responded curvilinearly with time for all treatments except halosulfuron-methyl (Table 4), but the ratings were low and not considered horticulturally significant in any of the treatments. Growth of winter jasmine was not affected by any herbicide treatment (data not presented).

Damage ratings of viburnums and hydrangeas treated with either rate of sulfosulfuron or trifloxysulfuron-sodium were curvilinearly related to rating date; however ratings of viburnums in all of these treatments were low and not likely of horticultural significance (Table 4). Viburnum growth in height and width was not affected by any herbicide (data not presented).

Damage ratings on hydrangeas were highest eight weeks after application with two 1× applications of sulfosulfuron and after four weeks on the 2× sulfosulfuron and trifloxysulfuron-sodium-treated plants. Plants treated with either sulfosulfuron treatment or trifloxysulfuron-sodium had higher damage ratings at every rating date than control plants or those sprayed with halosulfuron-methyl. Growth in height of hydrangeas was not affected by any herbicide treatment, but width decreased slightly with two 1× sulfosulfuron treatments (Table 2). Hydrangea plants receiving any herbicide treatment grew less in width than control plants.

A curvilinear relationship between time after herbicide application and damage ratings existed on weigela treated with trifloxysulfuron-sodium or two 1× applications of

Table 4. **Plant damage rating at 2, 4, 8, and 12 weeks after treatment of several plant species sprayed in 2009 with sulfosulfuron at 87.7 g·ha⁻¹ (1.2 oz·A⁻¹) (label rate, 1×) with a repeat spray 30 days later (1× + 1×), sulfosulfuron at 173.0 g·ha⁻¹ (2.4 oz·A⁻¹) (twice the label rate, 2×), trifloxysulfuron-sodium at 74.1 g·ha⁻¹ (1.0 oz·A⁻¹) (twice the label rate, 2×), halosulfuron-methyl at 182.4 g·ha⁻¹ (2.6 oz·A⁻¹) (2 times label rate, 2×), or tap water (control). All treatments included nonionic surfactant at 0.25% by volume. n = 6 for all treatments except redbud in which n = 5.**

	Plant damage rating[z]				
Weeks after treatment	Sulfosulfuron (1× + 1×)	Sulfosulfuron (2×)	Trofloxysulfuron-sodium	Halosulfuron-methyl	Control
			Crape myrtle		
2	0	0	6	0	0
4	1	1	36	0	0
8	18	18	18	18	17
12	6	8	6	4	5
Linear	**	**	**	*	**
Quadratic	**	**	**	**	**
Cubic	**	**	**	**	**
			Winter jasmine		
2	0	0	0	0	0
4	4	3	2	1	2
8	0	0	0	0	0
12	0	0	0	0	0
Linear	**	*	NS	NS	NS
Quadratic	**	NS	NS	NS	NS
Cubic	**	**	**	NS	**
			Viburnum		
2	0	0	0	0	0
4	3	3	7	1	0
8	6	5	7	1	0
12	1	1	2	1	0
Linear	NS	NS	NS	NS	NS
Quadratic	**	**	**	NS	NS
Cubic	NS	NS	*	NS	NS

…Continued

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Table 1. Continued

Weeks after treatment	Sulfosulfuron (1× + 1×)	Sulfosulfuron (2×)	Trofloxysulfuron-sodium	Halosulfuron-methyl	Control
	Plant damage rating[z]				
			Hydrangea		
2	6	5	18	0	1
4	19	22	29	0	0
8	29	11	15	0	0
12	8	4	7	1	0
Linear	NS	*	**	NS	NS
Quadratic	**	**	**	NS	NS
Cubic	NS	**	**	NS	NS
			Weigela		
2	6	6	36	8	0
4	10	5	89	5	0
8	19	6	92	7	1
12	5	6	85	1	0
Linear	NS	NS	**	*	NS
Quadratic	**	NS	**	NS	NS
Cubic	**	NS	**	NS	NS
			Euonymus		
2	2	0	0	0	1
4	1	1	0	0	1
8	0	0	0	0	0
12	0	0	0	0	0
Linear	**	NS	NS	NS	*
Quadratic	*	NS	NS	NS	NS
Cubic	NS	NS	NS	NS	NS
			Forsythia		
2	0	0	0	0	0
4	0	0	11	0	0
8	0	0	0	0	0
12	0	0	0	0	0
Linear	NS	NS	**	NS	NS
Quadratic	NS	NS	**	NS	NS
Cubic	NS	NS	**	NS	NS
			Redbud		
2	5	6	56	0	0
4	13	12	65	1	0
8	14	7	27	2	1
12	6	3	9	2	0
Linear	NS	NS	**	NS	NS
Quadratic	NS	NS	NS	NS	NS
Cubic	NS	NS	**	NS	NS
			Marigold		
2	0	0	34	2	0
4	0	1	30	0	0
8	4	6	14	2	4
12	3	2	4	1	0
Linear	NS	NS	**	NS	NS
Quadratic	NS	NS	NS	NS	NS
Cubic	NS	NS	NS	NS	NS

[z]Ratings were on a scale of 0 to 100 with 0 being a plant with no damage and 100 being a dead plant.

[NS, *, **]Not significant or significant at $P \leq 0.05$ or 0.01, respectively.

sulfosulfuron (Table 4). A decreasing linear relationship between time after application and damage ratings occurred with halosulfuron-methyl, but the damage ratings in this treatment were low and would not likely be noticeable to consumers. Some dieback occurred on weigela receiving trifloxysulfuron-sodium (Table 2), and two applications of sulfosulfuron decreased height of weigela plants. Control weigela plants had the greatest growth in height and width of the treatments.

Damage rating decreased curvilinearly with time after herbicide application on euonymus treated with two 1× applications of sulfosulfuron, but ratings were very low and damage would not likely be noticeable to consumers (Table 4). Growth in height and width were not affected by any herbicide treatment (data not presented).

Curvilinear relationships between time after application and damage ratings occurred for forsythia and redbud plants, but a decreasing linear relationship occurred for marigold

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plants treated with trifloxysulfuron-sodium (Table 4). On forsythia and redbud plants the greatest rating occurred four weeks after application, except on redbud sprayed with two 1× applications of sulfosulfuron in which the highest damage rating occurred eight weeks after application. Forsythia receiving trifloxysulfuron-sodium also had the least growth in width while plants receiving the two 1× applications of sulfosulfuron grew most in width and plants treated with halosulfuron-methyl and control plants were intermediate in growth (Table 2). Damage ratings of redbud treated with trifloxysulfuron-sodium were higher than those of other treatments at every rating date except eight weeks after treatment when damage ratings of plants sprayed with two 1× sprays of sulfusulfuron were similar to those of plants treated with trifloxysulfuron-sodium (Table 4). Some dieback occurred on redbud trees with trifloxysulfuron-sodium, but growth of redbuds treated with the other herbicides did not differ from that of the controls. Growth in width of marigold plants receiving either sulfosulfuron treatment was greater than that of plants in any other treatment, while growth in width of marigold plants treated with trifloxysulfuron-sodium was lower than that of control plants or plants sprayed with halosulfuron.

Generally application of trifloxysulfuron-sodium resulted in the greatest damage ratings of the herbicides tested, while halosulfuron-methyl generally resulted in little damage to the ornamental species. Redbud and weigela were damaged by all of the herbicides in 2008, while spirea and crape myrtle were damaged by all of the herbicides in 2009. Bachman (1) also noted phytotoxicity on ‘Carolina Beauty’ crape myrtle while McDaniel et al. (5) noted phytotoxicity on ‘Pink Lady’ weigela with halosulfuron-methyl. McDaniel et al. (5) noted phytoxicity on forsythia with halosulfuron-methyl. In the current study, halosulfuron-methyl did not damage forsythia during either year, but trifloxysulfuron-sodium damaged forsythia during both years. This difference in results with halosulfuron-methyl may have been due to use of a different adjuvant in our study or due to different environmental conditions either at the time of application or during the subsequent growing season.

Based on this study, all of the sulfonyl urea herbicides tested were safe to use on euonymus, but none should be used on redbud, weigela, spirea, or crape myrtle. Trifloxysulfuron-sodium appears to be the most likely to cause phytotoxicity on tested species except euonymus, while halosulfuron-methyl is least likely to cause phytotoxicity. Sulfosulfuron also should not be used on privet, hydrangea, or winter jasmine.

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