Growth Regulation of Russian Sage During Greenhouse and Nursery Production[1]

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Abstract

Growth response of *Perovskia atriplicifolia* (Russian sage) treated with several plant growth retardants (PGRs) was determined under three production regimes: 1) small plants in 10 cm (4 in) pots grown in a greenhouse and half transplanted into the landscape at 6 weeks after treatment (WAT), and 2) large plants grown in 3.8 liter (#1) pots in a greenhouse or 3) in an outdoor nursery. Plants in 3.8 liter (#1) pots were not transplanted into the landscape. Treatments included Cutless at 50, 100 and 150 ppm; Sumagic at 20, 40 and 60 ppm; B-Nine/Cycocel tank mixes at 2,500/1,500, 5,000/1,500 and 7,500/1,500 ppm; Pistill at 500 and 1,000 ppm; and a non-treated control. All PGRs controlled plant growth through 6 WAT in the greenhouse and 2 weeks after planting. At this time (8 WAT), plants treated with the most effective rate of Cutless (150 ppm), Sumagic (20, 40, or 60 ppm), B-Nine/Cycocel tank mixes (5,000 ppm/1,500 ppm), and Pistill (500 or 1,000 ppm) were 32%, 32%, 25%, and 32% smaller in 10 cm (4 in) pots and 21%, 22%, 22%, and 16% smaller in 3.8 liter (#1) pots, respectively, compared to non-treated controls. Treatment effects were non-significant by 4 weeks after plants grown in the greenhouse in 10 cm (4 in) pots for 6 weeks were transplanted into the landscape (10 WAT). Plants in 3.8 liter (#1) pots in the greenhouse were significantly smaller, excluding those treated with Pistill, than non-treated controls at 12 WAT; at this time, the most effective rate of Cutless (150 ppm), Sumagic (40 ppm), and B-Nine/Cycocel tank mixes (5,000 ppm/1,500 ppm) suppressed growth 21%, 23%, and 26%, respectively. For 3.8 liter (#1) pots in the nursery, Cutless suppressed growth 5–11% at 2 WAT only, and the most effective rate of Sumagic (60 ppm) reduced growth 7% at 4 WAT, but not thereafter. The most effective rates of B-Nine/Cycocel (7,500 ppm/1,500 ppm) and Pistill (1,000 ppm) suppressed growth 13% and 10%, respectively, at 8 WAT. Results suggest that PGR effectiveness is less outdoors under nursery conditions than in the greenhouse, particularly for Cutless and Sumagic. The duration and magnitude of B-Nine/Cycocel treatment effects suggest that this PGR combination may provide the most effective growth control of Russian sage under nursery conditions.

Index words: plant growth regulator, growth retardant.

Growth regulators used in this study: Cutless (flurprimidol), ∝-(1-methylethyl)-∝-[4-(trifluromethyoxy)phenyl]-5-pyrimidinemethanol; Sumagic (uniconizole-p), E-1-[4-chlorophenyl]-4,4-dimethyl-2-[1,2,4-triazol-1-yl] pent-1-ENE-3-ol; B-Nine (daminozide), butanedioic acid mono-(2,2-dimethylhydrazide) and Cycocel (chlormequat chloride), (2-chlorethyl) trimethylammonium chloride tank mixes; and Pistill (ethephon), (2-chloroethyl) phosphonic acid.

Species used in this study: Russian sage (*Perovskia atriplicifolia* Kar.).

Significance to the Nursery Industry

Plant growth retardant (PGR) effectiveness is a function of numerous factors including plant or pot size, physiological stage of plant development, nutrition, irrigation rate, and environmental conditions (2, 4, 11, 14). PGR labels usually reflect varying plant response under different conditions by giving a range of recommended rates, and suggesting that initial application be made to a small group of plants. However, most of the recommended rates for herbaceous perennials are usually based upon research conducted in greenhouses with plants in 10 cm (4 in) or smaller containers. Based on our research, PGRs are likely to be less effective under nursery conditions, and results suggested higher rates or repeated applications are needed when producing herbaceous perennials under nursery conditions. B-Nine/Cycocel tank mixes provided the most effective control under nursery conditions in this study, and may be the best option for controlling growth of Russian sage in the nursery.

Introduction

Perovskia atriplicifolia (Russian sage) is a grey-foliaged herbaceous perennial that produces terminal flower panicles throughout the summer, is well suited to dry sites, and has no photoperiod or vernalization requirement for flowering (3). Russian sage was the 1995 Perennial Plant Association Plant of the Year, and is a popular garden plant (1, 8). Despite its redeeming landscape characteristics, Russian sage is a rapidly growing perennial that can reach 1.5 m (5 ft) in height in one growing season, and it is often difficult to maintain in greenhouses and nurseries. Excessive growth can lead to blow-over in nurseries, plants out-growing their pots, reduced plant quality, and increased shipping costs. Pruning is an option for maintaining compact growth, however, this practice is often cost-prohibitive, particularly when used on a large scale.

Plant growth retardants (PGRs) can be an economical option for controlling growth, and often these chemicals also improve the quality and overall appearance of many plants including herbaceous perennials (5, 9, 10). B-Nine, Cycocel, Pistill, and Sumagic are labeled for use on herbaceous perennials in the greenhouse; B-Nine and Pistill may also be used in nurseries.

B-Nine and Cycocel are often applied as tank mixes, and the synergistic combination of these two chemicals appears to be one of the most effective chemical growth controls currently available (6). Cutless is labeled for use on turf, however, it has been effective in controlling growth of other horticultural crops (9). The growth retardants B-Nine, Sumagic, and B-Nine/Cycocel tank mixes were reported to control growth of Russian sage in the greenhouse (10). Banko and

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Stefani (5) reported Florel, another PGR with the same active ingredient as Pistill, and combinations of Florel and Sumagic or B-Nine to be effective in restricting growth of this species. Location was not specified in their study, however, methodology suggests that it was conducted under nursery conditions.

Previous unpublished research conducted at Auburn University with Mexican sage (*Salvia leucantha* Cav.) and 'Homestead Purple' verbena [*Verbena canadensis* (L.) Britt.] suggested that PGR effectiveness was less under nursery than greenhouse conditions. In that study, experimental conditions in the two production environments differed in numerous ways, including initial plant size, pot size, irrigation frequency, nutrition, growing substrate, light quality, environmental conditions, and possibly photoperiod. Under greenhouse conditions, plants are usually grown in 10 cm (4 in) or smaller pots, watered only as necessary, receive fertilizer as periodic liquid feed, and are not exposed to the rigors of unpredictable weather. In the nursery, plants are grown in large pots [3.8 liter (#1) or larger], watered according to the demands of a schedule and surrounding plants, receive time-released nutrients, and endure outdoor weather. Any of these conditions could result in a difference in plant response to PGRs (2, 4, 11, 14). The objective of this experiment was to determine the growth response of Russian sage grown in 3.8 liter (#1) pots to PGRs under outdoor nursery conditions. A second aspect of the study examined the response of Russian sage to the same PGR treatments when grown in 10 cm (4 in) and 3.8 liter (#1) pots in a greenhouse.

Materials and Methods

Greenhouse [10 cm (4 in) pots]. Rooted cuttings were transplanted on February 3, 1999, to 10 cm (4 in) square pots containing Fafard #3 (Fafard, Anderson, SC) and placed pot-to-pot in a double-poly greenhouse [heat set point: 20C (68F), ventilation set point: 25.6C (78F)]. Liquid fertilizer was applied weekly at 150 ppm N using a 20N–8.9P–16.6K fertilizer (20–20–20, Pro-Sol, Ozark, AL). On February 9, plants were sheared to 5 cm (2 in) above the pot rims, and spaced on 20 cm (8 in) centers.

PGR treatments were applied as foliar sprays after plants had approximately 2.5 cm (1 in) of new growth (February 26) using a CO_2 sprayer with a flat spray nozzle at 1.4 kg/cm^2 (20 psi) in volumes of 0.2 liter/m^2 (2 qt/100 ft^2). Treatments included: Cutless at 50, 100, or 150 ppm; Sumagic at 20, 40, or 60 ppm; B-Nine/Cycocel tank mixes at 2,500/1,500, 5,000/1,500, or 7,500/1,500 ppm; Pistill at 500 or 1000 ppm, and a non-treated control. At the time of treatment, temperature was 21.7C (71F) with a relative humidity of 77%. Plants were not irrigated until the following day.

Growth index [GI = (height + widest width + width perpendicular to first width) ÷ 3] was determined at two week intervals, starting at 2 weeks after treatment (WAT), and continued until treatment effects were no longer significant. At 6 WAT, half of the plants in each treatment were randomly selected and planted in outdoor ground beds to determine the persistence of PGR treatments in a landscape setting. Ground beds were 2.1 × 0.91 m (7 × 3 ft) plots amended with non-composted pine bark [screen size < 1.25 cm (0.5 in)] to a depth of 5.0–7.5 cm (2–3 in), tilled, and mulched with 2.5 cm (1 in) of pine bark. The pH varied with depth; 6.0–6.5 at 0–7.5 cm (0–3 in), and 5.5–6.0 at 7.5–15 cm (3–6 in). Plots were overhead irrigated when the upper 2.5 cm (1 in) of soil was dry, but before plants wilted. Control plants flowered 2 weeks after planting (WAP); at that time, the presence or absence of flowers was recorded on treated and non-treated plants. The experimental design was a randomized complete block with 10 single-plant replications in the greenhouse and 5 replications in the landscape.

3.8 liter (#1) pots (greenhouse and nursery). Methodology was identical for the greenhouse and nursery portion with 3.8 liter (#1) pots unless otherwise indicated. Dormant Russian sage were transplanted in March 1999 from 15 cm (6 in) pots to 3.8 liter (#1) pots containing a pine bark:sand (3:1 by vol) medium amended per m^3 (yd^3) with 7.1 kg (12 lb) of a 16.2N–2.6P–10K fertilizer (18–6–12, Polyon, Sylacauga, AL), 3.0 kg (5 lb) dolomitic limestone, and 0.9 kg (1.5 lb) Micromax. Plants were placed either in a heated greenhouse or outdoors in a nursery. In the greenhouse [heat set point: 20C (68F), ventilation set point: 25.6C (78F)], Russian sage was watered when the medium appeared dry, but before plants wilted. For the nursery portion, plants were grown outdoors in full sun and received overhead irrigation twice daily at a rate of approximately 1.25 cm (0.5 in) at each watering.

On May 7, Russian sage were pruned at 20 cm (8 in) above the pot rims, and treatments were applied when re-growth was about 2.5 cm (1 in) in length. The same PGR treatments used on Russian sage in 10 cm (4 in) pots were applied to plants in 3.8 liter (#1) pots on May 18. Both groups of plants in 3.8 liter (#1) pots were treated in a greenhouse to avoid overhead irrigation and the nursery grown plants were returned to outdoor conditions the following day. At treatment, temperature was 27.1C (82F) with a relative humidity of 94%.

Treatments were completely randomized and replicated with 9 single plants in the nursery and 5 single plants in the greenhouse. Similar data were collected as in the 10 cm (4 in) part of the greenhouse study. However, plants were not transplanted into the landscape due to non-significant or diminishing treatment effects in the nursery at 6 WAT; flowering data were not recorded because all plants were in flower 1 to 2 WAT. Treatment effects were still apparent in the greenhouse at 6 WAT, but these plants were not transplanted into ground beds to duplicate the treatment plants received in the nursery.

Data from both greenhouse and nursery studies were analyzed using general linear models, regression analysis, and mean separation among growth retardants across rates by Duncan's Multiple Range Test. The control was included in regression analysis, but not in mean separation analysis, and the probability level was $P = 0.05$. No statistical comparisons were made between the greenhouse and nursery studies, or between plants in 10 cm (4 in) and 3.8 liter (#1) pots indoors because of the lack of replication of growing locations.

Results and Discussion

Greenhouse [10 cm (4 in) pots]. Growth of Russian sage in the greenhouse [10 cm (4 in)] pots was reduced by all PGRs through 6 WAT (Table 1). Plants treated with the three rates of Cutless were 7%, 15–20%, and 12–28% smaller than controls at 2, 4, and 6 WAT, respectively. At 8 WAT, these plants were still 14–32% smaller than control plants after growing in the landscape for two weeks. Plants treated with Sumagic were 13%, 30%, and 32–36% smaller than control

Table 1. Growth index[z] of Russian sage grown in 10 cm (4 in) pots following treatment with several plant growth retardants in a greenhouse and after transplanting outdoors into ground beds.

Growth regulator	Rate (ppm)	Greenhouse			Landscape	
		2 WAT[y]	4 WAT	6 WAT	8 WAT	10 WAT
Control	0	15	20	25	28	32
Cutless	50	14	17	22	23	28
	100	14	16	20	24	31
	150	14 L*[x]	16 L***	18 L***	19 L**	27 NS
Mean[w]		14a	16a	20a	22ab	29a
Sumagic	20	13	14	17	19	25
	40	13	14	17	19	29
	60	13 L*Q**	14 L***Q***	16 L***Q***	19 L**Q*	26 NS
Mean		13a	14b	16b	19b	27a
B-Nine/Cycocel	2,500/1,500	14	17	20	22	29
	5,000/1,500	14	16	20	21	29
	7,500/1,500	14 Q*	16 L**Q***	20 L*Q**	24 Q*	30 NS
Mean		14a	16a	20a	23a	29a
Pistill	500	14	16	18	19	28
	1,000	13 L***	14 L***	16 L**	19 L**	26 NS
Mean		13a	15b	17b	19b	27a

[z]Growth index = (height + widest width + width perpendicular) ÷ 3, in cm.

[y]WAT = weeks after treatment; Russian sage were transplanted into ground beds at 6 WAT.

[x]Regression response non-significant (NS), linear (L) or quadratic (Q) at the 0.05 (*), 0.01 (**), or 0.001 (***) level; control included in regression analysis.

[w]Mean separation among growth retardants across rates by Duncan's Multiple Range Test (P = 0.05); control not included in analysis.

plants at 2, 4, and 6 WAT, respectively. Sumagic-treated plants were 32% smaller than controls at 8 WAT, however, by 10 WAT, size differences were non-significant in the landscape. For plants treated with B-Nine/Cycocel tank mixes, shoot growth was suppressed 7%, 15–20%, and 20% at 2, 4, and 6 WAT, with GI of treated plants still 14–25% less than that of control plants at 8 WAT. In the landscape, all plants recovered rapidly from PGR treatment effects (Table 1). The rate of growth for non-treated controls did not change much after they were transplanted into the ground; plants grew 7 cm (2.8) between 6 and 10 WAT. However, PGR-treated plants grew 6–12 (2.4–4.7 in) cm over the same time period. Application of Cutless, Sumagic, or B-Nine/Cycocel tank mixes did not affect the overall appearance of plants (excluding size); leaves and flowers were similar to those on non-treated plants and no phytotoxicity was observed. These results agree with those of Latimer et al. (10) who reported B-Nine, B-Nine/Cycocel tank mixes, and Sumagic to control growth of Russian sage. Data herein did differ from Latimer et al. (10) in that they reported Sumagic at 45 and 60 ppm provided more persistent control that was still significant at 10 WAT which they considered to be undesirable.

Pistill-treated plants were 7–13%, 20–30%, and 28–36% smaller than control plants at 2, 4, and 6 WAT, respectively. At 8 WAT, these plants were 32% smaller than control plants, and flowers were present on only 40% of Pistill-treated plants while all control plants were flowering (data not shown). Flowering delay is a common side effect with Pistill application. In unpublished research conducted at Auburn University, Pistill delayed flowering in verbena, and materials containing the same active ingredient (ethephon) delayed flowering of chrysanthemum (*Dendranthema grandiflora* Tzvelev.) and New Guinea impatiens (*Impatiens* x *hawkeri*) (13, 15). Additionally, terminal leaves on Pistill-treated plants, but not on controls, appeared to be smaller than leaves towards the base of the plants. Banko et al. (5) reported that ethephon delayed flowering of Russian sage 7–10 days. At 10 WAT, plants treated with Pistill were similar in size to control plants and were flowering in the landscape.

Growth suppression was similar for all PGRs at 2 WAT. At 4 and 6 WAT, plants treated with Sumagic or Pistill were smaller than those treated with Cutless or B-Nine/Cycocel tank mixes, and smaller than those treated with B-Nine/Cycocel tank mixes at 8 WAT. By 10 WAT, there were no statistically significant size differences among PGR-treated plants.

Greenhouse [3.8 liter (#1) pots]. For plants treated with Cutless, effects on growth were not apparent until 4 WAT (Table 2). After that time, growth was retarded 7–22%, 9–25%, and 6–21% at 4, 6, and 8 WAT, respectively. Sumagic-treated plants were 0–17%, 16–23%, 12–23%, and 11–22% smaller than control plants at 2, 4, 6, and 8 WAT, respectively. Growth of plants treated with B-Nine/Cycocel tank mixes was suppressed 17–24%, 25–33%, 21–27%, and 16–22%, while application of Pistill resulted in reductions in GI of 17–24%, 32–36%, 22–27%, and 12–16% at 2, 4, 6, and 8 WAT, respectively. At 2 and 4 WAT, B-Nine/Cycocel tank mixes and Pistill provided more control of growth than Cutless or Sumagic, and at 6 WAT, they were more effective than Cutless (Table 2). At 8 WAT, growth suppression was similar among PGRs. At 10 and 12 WAT, GI was reduced by all PGRs except Pistill, however, plants exhibited shoot dieback and decreased vigor, probably due to increased heat, and being pot-bound, so data are not presented or further discussed.

Nursery. Growth control provided by Cutless was inconsistent in the nursery throughout the experiment (Table 3). At 2 WAT, Cutless-treated plants were 5–11% smaller than

Table 2. Growth index[z] of Russian sage grown in 3.8 L (#1) pots following treatment with several plant growth retardants under greenhouse conditions.

Growth regulator	Rate (ppm)	Growth index			
		2 WAT[y]	4 WAT	6 WAT	8 WAT
Control	0	41	73	81	85
Cutless	50	40	67	73	80
	100	38	68	74	74
	150	41 NS[x]	57 L**	61 L***	67 L***
Mean[w]		39a	64a	70a	74a
Sumagic	20	41	61	65	71
	40	35	61	71	76
	60	34 L**	56 L***	62 L***	66 L***
Mean		37a	59a	65ab	71a
B-Nine/Cycocel	2,500/1,500	32	55	64	71
	5,000/1,500	31	49	59	65
	7,500/1,500	34 L*Q**	50 L***Q**	59 L***Q*	66 L***Q*
Mean		32b	52b	61b	67a
Pistill	500	34	50	59	71
	1,000	31 L***	47 L***Q*	63 L***Q**	75 L*Q*
Mean		32b	49b	61b	73a

[y]Growth index = (height = + widest width + width perpendicular) ÷ 3, in cm.

[y]WAT = weeks after treatment.

[x]Regression response non-significant (NS), linear (L) or quadratic (Q) at the 0.05 (*), 0.01 (**), or 0.001 (***) level; control included in regression analysis.

[w]Mean separation among growth retardants across rates by Duncan's Multiple Range Test (P = 0.05); control not included in analysis.

controls, but Cutless treatments were non-significant at 4 and 8 WAT. At 6 WAT, there was a quadratic response to increasing rates of Cutless; plants given the lowest rate were 9% larger than non-treated plants, while those treated with the highest rate were 4% smaller than control plants. For Sumagic-treated plants, growth was suppressed 7–14% at 2 WAT. At 4 WAT, increased rates of Sumagic resulted in a linear decrease in GI, however, the greatest control was only 7%. Under nursery conditions, growth control with one application of either Cutless or Sumagic at the rates tested had little practical benefit. Control of GI with Cutless or Sumagic in the nursery appeared to be of shorter duration and lower

Table 3. Growth index[z] of Russian sage grown in 3.8 liter (#1) pots following treatment with several plant growth retardants in a nursery.

Growth regulator	Rate (ppm)	Growth index				
		2 WAT[y]	4 WAT	6 WAT	8 WAT	10 WAT
Control	0	44	58	70	78	75
Cutless	50	42	60	77	81	.[y]
	100	39	55	73	79	.
	150	39 L*[x]	56 NS	67 Q**	82 NS	.
Mean[w]		40a	57a	73a	81a	
Sumagic	20	41	58	77	83	.
	40	39	55	69	75	.
	60	38 L***	54 L*	73 NS	79 NS	.
Mean		40a	56a	73a	79a	
B-Nine/Cycocel	500/1,500	41	50	63	70	70
	5,000/1,500	38	49	63	71	71
	7,500/1,500	37 L***	48 L***Q*	59 L***	68 L**	72 NS
Mean		39a	49b	62b	70b	71b
Pistill	500	36	48	61	75	77
	1,000	33 L***Q*	43 L***	51 L***	70 L*	80 NS
Mean		34b	45c	56c	72b	79a

[z]Growth index = (height + widest width + width perpendicular) ÷ 3, in cm.

[y]WAT = weeks after treatment; data were not collected on Cutless or Sumagic-treated plants due to lack of significance at 8 WAT.

[x]Regression response non-significant (NS), linear (L) or quadratic (Q) at the 0.05 (*), 0.01 (**), or 0.001 (***) level; control included in regression analysis.

[w]Mean separation among growth retardants across rates by Duncan's Multiple Range Test (P = 0.05); control not included in analysis.

magnitude than in the greenhouse with plants in 10 cm (4 in) or 3.8 liter (#1) pots.

B-Nine/Cycocel tank mixes and Pistill were more effective than Cutless or Sumagic at 4, 6, and 8 WAT (Table 3). Control with these chemicals appeared to be less than that obtained under greenhouse conditions. Plants treated with B-Nine/Cycocel tank mixes were 7–16%, 14–17%, 10–16%, and 9–13% smaller than non-treated plants at 2, 4, 6, and 8 WAT, respectively, but similar at 10 WAT. Under greenhouse conditions, the range of control of plants in 3.8 liter (#1) pots with B-Nine/Cycocel tank mixes was 17–33% through 8 WAT. Plants treated with B-Nine/Cycocel tank mixes and grown in 10 cm (4 in) pots were 14–21% smaller than control plants after growing in ground beds for 2 weeks (8 WAT). Growth of Pistill-treated plants outdoors was retarded 18–25%, 17–26%, 13–27%, and 4–10% at 2, 4, 6, and 8 WAT, respectively, as compared to control plants, but the effects were non-significant at 10 WAT.

For all PGRs applied, growth suppression appeared to be less under nursery conditions compared to greenhouse conditions. Similar differences in plant response to PGRs under greenhouse and nursery conditions were also seen in Mexican sage and 'Homestead Purple' verbena (unpublished data at Auburn University). However, both B-Nine/Cycocel tank mixes and Pistill provided more effective size control under nursery conditions than Cutless or Sumagic. B-Nine/Cycocel tank mixes may be a better choice for size control under nursery conditions because results obtained in the greenhouse portion of this test with 10 cm (4 in) pots and results reported by other researchers suggest delayed flowering with Pistill (5, 13, 15).

Growth control from Cutless and Sumagic in the greenhouse, even when applied to large plants grown in 3.8 liter (#1) pots, appeared to be more effective and of greater persistence than under nursery conditions. A possible factors contributing to decreased PGR effectiveness in the nursery is plants in the nursery are watered more frequently and with higher volumes than applied in the greenhouse, resulting in increased plant growth (2, 4, 11, 12, 14). Application of paclobutrazol to chrysanthemum was less effective when plants received high irrigation rates (7). While B-Nine/Cycocel tank mixes provided significant growth control for 8 weeks under nursery conditions, plant appearance would have been improved if size control had been greater; this would probably require higher rates or multiple applications.

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