Growth Regulation of Mexican Sage and 'Homestead Purple' Verbena During Greenhouse and Nursery Production[1]

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Abstract

Salvia leucantha (Mexican sage) and *Verbena canadensis* 'Homestead Purple' were treated with the plant growth retardants (PGRs), Cutless, Sumagic, B-Nine/Cycocel tank mixes, or Pistill under both greenhouse and nursery conditions. Increasing rates of all PGRs applied to both species reduced plant size in the greenhouse for 6 weeks after treatment (WAT). Growth reduction of Mexican sage with the most effective rate (providing greatest growth control) of each PGR over this period averaged 11% with Cutless, 15% with Sumagic, 23% with B-Nine/Cycocel tank mixes, and 25% with Pistill. For verbena, size control with the most effective rate of each PGR averaged 15% with Cutless, 18% with Sumagic, 27% with B-Nine/Cycocel tank mixes, and 29% with Pistill. After transplanting greenhouse-grown plants into outdoor ground beds, only Mexican sage treated with B-Nine/Cycocel were significantly smaller 4 weeks after planting (WAP). Greenhouse-grown verbena treated with Sumagic, B-Nine/Cycocel tank mixes, and Pistill and planted in the landscape were 15–23%, 18–25%, and 0–20% smaller, respectively, than control plants at 2 WAP, but by 4 WAP, all PGR-treated verbena were similar in size to control plants. Under nursery conditions, Cutless and B-Nine/Cycocel tank mix reduced Mexican sage size up to 4 WAT. None of the PGRs affected plant size at 6 WAT. The most effective rate of each PGR (averaged over the duration that a PGR was significant) suppressed shoot growth 16% for Cutless, 12% with Sumagic, 20% for B-Nine/Cycocel tank mixes, and 29% for Pistill. For verbena only, Sumagic suppressed growth up to 10% at 2 WAT, and no PGR effectively controlled growth under nursery conditions 4 WAT.

Index words: plant growth regulator, greenhouse production, nursery production.

Growth regulators used in this study: Cutless (flurprimidol), α-(1-methylethyl)-α-[4-(trifluromethyoxy)phenyl]-5-pyrimidinemethanol; Sumagic (uniconazole), 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: Mexican sage (*Salvia leucantha* Cav.) and 'Homestead Purple' verbena (*Verbena canadensis* (L.) Britt.[*V. Aubletia* Jacq.; *Glandularia canadensis* (L.) Small.] 'Homestead Purple').

Significance to the Nursery Industry

Most PGR rates for use on herbaceous plants are based on research conducted in greenhouses. However, our research suggests that rates recommended for use under greenhouse conditions are less effective in controlling growth of plants produced in the nursery. For example, growth control of Mexican sage was less persistent, only lasting up to 4 weeks in the nursery compared with 6–8 weeks under greenhouse conditions. For verbena, growth control was adequate in the greenhouse, with all PGR-rate combinations providing an average of 17% (up to 33%) control for 6 weeks. Under nursery conditions, only Sumagic provided any growth control (0–10%) which was of limited practical benefit; by 4 WAT, there was no growth control with any PGR. With the outdoor production of herbaceous perennials under nursery conditions increasing, it is vital for growers to understand that PGR efficacy may be less under outdoor nursery conditions than under greenhouse production regimes. Multiple PGR applications or higher rates may be necessary to control growth in the nursery.

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Introduction

Salvia leucantha (Mexican sage) and *Verbena canadensis* 'Homestead Purple' ('Homestead Purple' verbena) are herbaceous perennials that provide unique additions to many landscapes; in 1995, *Salvia* was among the top twenty perennial genera sold to consumers in the United States, and *Verbena* was among the top twenty perennials sold in the southern United States (13). Mexican sage produces spikes of attractive purple flowers that envelop the plant in the fall when few other plants are in bloom; additionally, it is a bee and butterfly attractant. However, Mexican sage presents a challenge to growers who wish to produce and market the plant in flower because it can grow 1 to 1.2 m (3 to 4 ft) in a single growing season. Additionally, it is a quantitative short-day plant for flowering, and under natural conditions will reach its aesthetic peak in fall (2, 3). Because most growers transplant plugs or rooted cuttings in the spring, Mexican sage could have a growing season of 5–6 months before it is marketed in flower. During this time, it can grow quite large and become difficult to manage in 3.8 liter (#1) or smaller containers.

Verbena canadensis and its cultivars are some of the most popular herbaceous perennials in the landscape due to their floriferous and durable nature. However, verbena can quickly spread up to 90 cm (36 in) and often requires repeated pruning or transplanting to a larger pot for maintenance in a nursery or greenhouse environment (1, 2). For the nursery or greenhouse grower, excessive growth of either Mexican sage or verbena can lead to blow-over, plants outgrowing their pots, excessive drying between irrigations, increased shipping costs, and leggy, unmarketable plants.

PGRs, including Cutless, Sumagic, B-Nine/Cycocel tank mixes, and Pistill, are effective in controlling growth of numerous horticultural crops, including many herbaceous perennials (7, 9, 10, 14). Sumagic and Cycocel are currently labeled for use on herbaceous species in greenhouses, but not in nurseries outdoors. B-Nine and Pistill are labeled for use on herbaceous perennials in greenhouses and outdoor nurseries. Even though Sumagic and Cycocel are not labeled for use outdoors, many nurseries have double-poly houses or poly-covered cold frames under which these chemicals may be applied. The tank mix of B-Nine and Cycocel is becoming more common due to a synergistic response, providing control in situations where other chemicals alone are less effective (6). Cutless is labeled for use on turf, however, research indicates that this PGR may be useful in controlling growth of horticultural crops (9).

Most research examining height control of herbaceous perennials has been conducted under greenhouse conditions with plants in small containers, usually 10 cm (4 in) or smaller. In the northeastern United States, herbaceous perennials are produced primarily in greenhouses, but in the South they are a mainstay in outdoor nurseries where they are typically produced in containers larger than 10 cm (4 in). Personal observation and general literature on the use of PGRs suggest that the effectiveness of PGRs may be less under nursery conditions than in greenhouse production due to differences in plant and pot sizes, physiological stage of plant development at the time of application, irrigation rates, weather, and crop nutrition (5, 6, 11, 15). Reductions in the effectiveness of PGRs under nursery conditions would require growers to consider using higher rates or multiple applications of PGRs to achieve the desired growth control. The objective of this study was to determine the growth response of Mexican sage and 'Homestead Purple' verbena to several PGRs under typical greenhouse and nursery conditions in the southeastern United States.

Materials and Methods

The materials and methods are presented for both species together; where dates differ, they are listed for Mexican sage followed by 'Homestead Purple' verbena.

Greenhouse study. Rooted cuttings were transplanted on February 3 and February 24, 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)). Mexican sage, a quantitative short-day plant for flowering (3), received night-break lighting from 10:00 PM–2:00 AM CST using incandescent lamps with a minimum of 0.93 w/m^2 beginning on February 9 and ending at treatment application (February 26). Verbena, a facultative long day to day neutral plant for flowering (17), were not placed under night-break lighting. 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 and March 11, plants were sheared to 5 cm (2 in) above the pot rims and 5 cm (2 in) beyond the edges of pot rims for verbena. Plants were spaced on 20 cm (8 in) centers after pruning. PGR treatments were applied as foliar sprays after plants had approximately 2.5 cm (1 in) of new growth (February 26, March 24) 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, respectively; Pistill at 500 or 1000 ppm; and an untreated control. At the time of treatment, temperatures were 21.7C (71F) and 25.6C (78F) with relative humidities of 77% and 60%. Plants were not irrigated until the following day.

At 6 weeks after treatment (WAT), half of the plants in each treatment were planted in outdoor ground beds to determine the persistence of PGR treatments in a landscape setting. Mexican sage were planted on 30 cm (12 in) centers in 1.95 m^2 (7 × 3 ft) tilled plots containing an organic soil, amended with non-composted pine bark (screen size <12.5 mm (0.5 in)) to a depth of 5–7.5 cm (2–3 in), and mulched with 2.5 cm (1 in) of pine bark. Overhead irrigation was applied when the soil under the mulch felt dry below 2.4 cm (1 in) but before plants wilted. Verbena were planted on 30 cm (12 in) centers in a Marvyn sandy loam soil containing 78.6% sand, 17.1% silt, and 4.3% clay and with a CEC of 4.44 meq/100 g; no supplements were added and plants were mulched with 2.5 cm (1 in) of pine bark. Plants were irrigated via ground-level trickle irrigation when the soil was dry to the touch at a depth of 2.5 cm (1 in) below the mulch.

The experimental design was a randomized complete block with 8 single-plant replications for Mexican sage and 10 single-plant replications for verbena. The experimental design was maintained after planting in ground beds. Growth

Table 1. Growth index[z] of Mexican sage following treatment with several plant growth retardants in the greenhouse and after transplanting outdoors into ground beds.

Growth retardant	Rate (ppm)	Greenhouse 2 WAT[y]	Greenhouse 4 WAT	Greenhouse 6 WAT	Landscape 2 WAP[y]	Landscape 4 WAP
Control	0	20	29	34	36	47
Cutless	50	20	27	34	38	47
	100	20	26	33	36	48
	150	18	25	31	34	46
Significance[x]		L**	L***	L***	NS	NS
Sumagic	20	18	26	33	35	47
	40	17	24	30	35	45
	60	17	24	31	35	47
Significance		L***	L***Q*	L***	NS	NS
B-Nine/Cycocel	2,500/1,500	17	22	26	30	44
	5,000/1,500	18	21	26	31	42
	7,500/1,500	17	21	25	27	37
Significance		L***Q*	L***Q***	L***Q***	L***	L**
Pistill	500	16	24	30	33	43
	1,000	14	21	28	32	47
Significance		L***	L***	L***	L*	NS

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

[y]WAT = weeks after treatment; WAP = weeks after planting in ground beds; 2 WAP corresponded to 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.

Table 2. **Growth index[z] of 'Homestead Purple' verbena following treatment with several plant growth retardants in the greenhouse and after transplanting outdoors into ground beds.**

Growth retardant	Rate (ppm)	Greenhouse			Landscape	
		2 WAT[y]	4 WAT	6 WAT	2 WAP[y]	4 WAP
Control	0	24	35	40	40	44
Cutless	50	23	33	37	36	45
100	21	33	35	34	43	
150	20	30	34	36	43	
Significance[x]		L^{***}	NS	L^{**}	NS	NS
Sumagic	20	21	31	35	34	45
40	20	32	36	33	44	
60	19	30	33	31	46	
Significance		L^{***}	NS	L^{**}	L^{**}	NS
B-Nine/	2,500/1,500	18	28	33	33	42
Cycocel	5,000/1,500	17	25	31	30	41
	7,500/1,500	18	26	32	31	41
Significance		$L^{***}Q^{***}$	$L^{***}Q^{*}$	$L^{***}Q^{*}$	L^{**}	NS
Pistill	500	20	29	36	41	45
	1,000	16	24	32	32	42
Significance		L^{***}	L^{***}	L^{***}	L^{*}	NS

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

[y]WAT = weeks after treatment; WAP = weeks after planting in ground beds; 2 WAP corresponded to 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.

Table 3. **Growth index[z] of Mexican sage following treatment with several plant growth retardants in the nursery.**

Growth retardant	Rate (ppm)	Growth index	
		2 WAT[y]	4 WAT
Control	0	42	56
Cutless	50	39	50
	100	38	52
	150	35	48
Significance[x]		L^{***}	L^{**}
Sumagic	20	40	53
	40	38	55
	60	37	52
Significance		L^{**}	NS
B-Nine/	2,500/1,500	38	55
Cycocel	5,000/1,500	37	50
	7,500/1,500	33	46
Significance		L^{***}	L^{***}
Pistill	500	35	53
	1,000	30	50
Significance		L^{***}	NS

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

[y]WAT = weeks after treatment.

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

index (GI = (height + widest width + width perpendicular) ÷ 3) was determined at two week intervals, starting at 2 WAT, until treatment effects were no longer significant. For verbena, the presence, but not number, of flowers was recorded at 4 WAT when controls were in full flower. This measurement was not collected for Mexican sage because the experiment was conducted in spring and the plant naturally flowers in the fall.

Nursery study. Mexican sage were transplanted on March 17, 1999, from 10 cm (4 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 time-released 18N–2.6P–10K fertilizer (18–6–12, Polyon, Sylacauga, AL), 3.0 kg (5 lb) dolomitic lime, and 0.9 kg (1.5 lb) Micromax. Plants were placed outdoors in full sun and received overhead irrigation twice daily. Commercial plugs of verbena were transplanted to 3.8 liter (#1) pots containing the same substrate on October 21, 1998, and over-wintered pot-to-pot outdoors. On April 11, verbena were pruned 5 cm (2 in) outside the pot rims, and on May 7, Mexican sage were pruned 20 cm (8 in) above the pot rims. The same PGR treatments used for the greenhouse portion were applied to the plants in 3.8 liter (#1) pots on May 18. Plants were treated in a greenhouse to avoid overhead irrigation but returned to nursery conditions the following day; ambient temperature was 27.1C (82F) with a relative humidity of 94% at treatment.

Treatments were completely randomized and replicated with 9 single plants of Mexican sage and 10 single plant replications of verbena. Similar data were collected as in the greenhouse study, however, plants were not transplanted into the landscape due to non-significant treatment effects at 6 WAT. Data for both the greenhouse and nursery studies were analyzed using general linear models and regression analysis, and the two species were analyzed as separate experiments. The accepted probability level was P = 0.05. No direct statistical comparisons were made between the greenhouse and nursery studies because of the lack of replication of locations.

Results and Discussion

Greenhouse study (Salvia leucantha). Increasing rates of all PGRs significantly reduced GI of Mexican sage through 6 WAT in the greenhouse (Table 1). Across all rates, Cutless suppressed GI by 0–10%, 7–14%, and 0–9% at 2, 4, and 6 WAT, respectively, compared to controls. With Sumagic, GI was 10–15%, 10–17%, and 3–12% less than that of controls at 2, 4, and 6 WAT, respectively. GI was 10–15%, 24–28%, and 24–26% less for plants treated with B-Nine/Cycocel tank mixes compared to controls at 2, 4, and 6 WAT, respectively. Finally, for Pistill, GI was suppressed 20–30%, 17–28%, and 12–18% at 2, 4, and 6 WAT, respectively, compared to GI non-treated plants. Of the rates tested, Cutless and Pistill were most effective in suppressing growth at the highest rates, Sumagic was equally effective at 40 and 60 ppm, and all rates of B-Nine/Cycocel tank mixes provided similar control.

Table 4. **Growth index of 'Homestead Purple' verbena following treatment with several plant growth retardants in the nursery.**

Growth retardant	Rate (ppm)	Growth index[z] 2 WAT[y]
Control	0	31
Cutless	50	30
	100	27
	150	30
Significance[x]		NS
Sumagic	20	31
	40	29
	60	28
Significance		L*
B-Nine/ Cycocel	2,500/1,500	31
	5,000/1,500	29
	7,500/1,500	31
Significance		NS
Pistill	500	27
	1,000	28
Significance		NS

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

[y]WAT = weeks after treatment.

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

After Mexican sage were transplanted into ground beds, GI of plants treated with Cutless or Sumagic was not significantly different from that of non-treated plants at 2 WAP. GI of plants treated with Pistill was 8–11% smaller than non-treated controls 2 WAP, but similar at 4 WAP. Growth index of plants treated with B-Nine/Cycocel was significantly different from that of non-treated controls for the greatest length of time; at 2 WAP , plants were 17–25% smaller than controls, and at 4 WAP, treated plants were 6–21% smaller. By 6 WAP in the landscape, growth retarding effects of B-Nine/ Cycocel were non-significant (data not shown). Lack of persistent growth control with Cutless, Sumagic, Pistill, and to a lesser extent, B-Nine/Cycocel tank mixes after plants were transplanted into the landscape indicates consumers can expect normal growth following purchase of plants treated with these PGRs. These results agree with those of Latimer et al. (10) who reported Sumagic and B-Nine/Cycocel tank mixes applied to Mexican sage in the greenhouse to be non-persistent by 4 WAP.

Greenhouse study (Verbena canadensis 'Homestead Purple'). All PGRs retarded shoot growth at 2, 4, and 6 WAT, except Cutless and Sumagic at 4 WAT; even then, there was a trend for plants to be smaller than controls (Table 2). Cutless reduced GI 4–17% and 8–15% at 2 and 6 WAT, respectively, and treatment effects were non-significant by 2 WAP in the landscape. Sumagic retarded GI 13–21% and 10–18% at 2 and 6 WAT, respectively, and 15–23% at 2 WAP, but its effect was non-significant at 4 WAP in the landscape. B-Nine/ Cycocel tank mixes suppressed GI 25–29%, 20–29%, and 18–23% at 2, 4, and 6 WAT, respectively. At 2 WAP this combination still provided significant control, with an 18–25% growth suppression compared to non-treated plants; however, at 4 WAP, treatment effects were non-significant.

Pistill suppressed growth 17–35%, 17–31%, and 10–20% at 2, 4, and 6 WAT, respectively, compared to non-treated plants. It was the only PGR that caused a delay in flowering at 4 WAT; 20% of plants treated with the low rate and 80% of plants treated with the high rate of Pistill were not in flower while all control plants were flowering. By 6 WAT, all plants sprayed with the low rate were in flower, and 80% of plants treated with the high rate were in bloom (data not shown). It is not uncommon for Pistill to delay flowering. In previous research, chrysanthemum and New Guinea impatiens treated with materials containing ethephon (the active ingredient in Pistill) had flowering delays that increased with increasing application numbers (12, 16). Two WAP, plants receiving the high rate of Pistill were 20% smaller than controls, however, those receiving the low rate had a similar GI to non-treated plants. By 4 WAP, GI was similar for Pistill-treated and control plants.

Nursery study (Salvia leucantha). As in the greenhouse, increasing rates of all PGRs reduced GI at 2 WAT, but only Cutless and B-Nine/Cyccocel tank mix provided significant GI reduction through 4 WAT (Table 3). No significant growth suppression occurred 6 WAT with any PGR (data not shown). For Cutless, GI was reduced 7–17% at 2 WAT and 7–14% at 4 WAT compared to non-treated plants. Sumagic and Pistill reduced GI by 4–12% and 17–29%, respectively, at 2 WAT compared to controls. For B-Nine/Cycocel tank mixes, GI was reduced 10–21% at 2 WAT, and by 2–18% at 4 WAT, compared to controls. Thus, a single application of any of these PGRs at the rates tested would not provide extended control of growth in a nursery environment, where the need for height control may be greater than in greenhouses due to problems with blow-over.

Nursery study (Verbena canadensis 'Homestead Purple'). Under nursery conditions, only Sumagic significantly reduced shoot growth at 2 WAT (Table 4), and none of the PGRs suppressed GI thereafter (data not shown). The minimal reduction in GI provided by Sumagic at 2 WAT (0–10%) would be of limited benefit in controlling the growth of this sprawling perennial. Previous research (4) indicated that Pistill controls growth of 'Homestead Purple' verbena, and although the location for the experiment was not specified, methodology indicated that it was probably conducted in the nursery. It is possible that the results from this experiment differ from those previously reported due to differences in initial plant size or age.

In conclusion, under greenhouse conditions, all of the PGRs provided excellent size control of Mexican sage. Conversely, all of the PGRs reduced Mexican sage GI at 2 WAT under nursery conditions, but only Cutless and B-Nine/ Cycocel tank mix suppressed growth 4 WAT. By 6 WAT in a nursery setting, no PGR reduced the size of Mexican sage. The difference in 'Homestead Purple' verbena's response to PGRs in the two locations was more dramatic. All PGRs provided adequate control through 6 WAT in the greenhouse. Sumagic provided minimal control only at 2 WAT in the nursery, but no other PGR provided control of growth in that location. This research shows that PGRs have good growth retarding effects under greenhouse conditions, but under nursery conditions their effects are less persistent and vary with species treated. Although the experimental design did not allow direct statistical comparisons between the two locations, differences were obvious. These differences may be due to higher irrigation rates or larger plant sizes at treatment application under nursery conditions (5, 6, 8, 11, 15). As plants increase in size, PGR efficacy decreases (15), and plants in the nursery are usually larger than in the greenhouse if grown in larger containers. Additionally, since nursery plants are usually grown in larger containers, it follows that they will have a greater capacity for growth during a single season. Water stress has been indicated as a non-chemical control of plant growth (5), and it follows that heavy irrigation supplied under nursery conditions may cause increased growth, transpiration, and uptake of PGRs. Barrett and Nell (8) reported efficacy of Bonzi was greater when treated plants received low fertility levels and were under drought stress; efficacy of Bonzi was the least when plants were well watered and fertilized. Plants in the greenhouse received water when they were dry, but before wilting was apparent; in the nursery plants were watered via overhead irrigation twice daily regardless of plant condition and received additional water via rainfall. These differences in irrigation rates could explain decreased PGR efficacy in the nursery. Response differences are possibly due to a combination of these, and perhaps other factors. This study indicates the need for additional research with either higher PGR concentrations than currently used in greenhouse production or multiple applications to increase the longevity of control under nursery conditions.

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