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Growth control and flower promotion of *Salvia* with benzyladenine foliar sprays

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Abstract

Foliar sprays of benzyladenine (BA) at concentrations of 100 to 1600 mg L^{-1} were applied 14 days after potting (DAP) onto *Salvia nemorosa* (L.) 'Caradonna' to determine if it would increase branching and flowering. At 28 DAP, BA foliar sprays ≥ 400 mg L^{-1} controlled plant height, ≥ 200 mg L^{-1} resulted in smaller plant diameter, 100 mg L^{-1} controlled growth index and inhibited flowering. Phytotoxicity in the form of leaf edge necrosis was observed at 1600 mg L^{-1} BA. Flowering was delayed by two to three weeks with ≥ 400 mg L^{-1} BA, however the plants were more compact, and the total number of flower stalks produced increased by 350 %. Total growing time to achieve maximum increased flower stalk number was an additional 21 days and growers will have to determine if the trade-off of flower delay is worth having more compact plants with 350 % more flowers. In a second experiment, BA was applied 13 DAP as a foliar spray at 0, 125, 250 and 500 mg L^{-1} to Salvia 'Ultra Violet', Salvia Marcus®, and Salvia 'May Night'. Plant height, number of flowering shoots, and flowering dates were recorded. Growth control effect was not observed with BA on 'Ultra Violet' plants, and control effect was limited and inconsistent for both 'May Night' and Marcus®. Thus, cultivar response to BA varies, and individual trials will have to be conducted to determine BA suitability as a growth enhancer.

Key words: 6-Benzylaminopurine, N6-Benzyladenine, Configure, cytokinin, meadow sage, plant growth regulator

Introduction

Salvia species have long been popular as summer annuals and culinary herbs in gardens around the world because of their beautiful flowers and aromatic leaves. *Salvia nemorosa* 'Caradonna' is a perennial sage that produces tall flower stalks with numerous small purple flowers (Nau, 1996). In production, unpinched plants form a single, tall stalk with limited branching. Tall plants are more difficult to transport, and shipping efficiency decreases because fewer plants fit on shipping carts (Pilon, 2006). Plant growth regulators (PGR) are applied to control plant height, with two to three foliar applications of daminozide being sprayed on a weekly basis (Pilon, 2006). Cytokinins can also be used to induce branching, control plant growth, and influence flowering (Boyle, 1992; Carpenter and Beck, 1972; Henny, 1986; Hoover *et al.*, 1998). The objectives of this research were to determine if foliar sprays of benzyladenine (Configure, Fine Americas, Inc., Walnut Creek, CA), a cytokinin-based PGR, could influence the branching, growth, and flowering of *S. nemorosa* 'Caradonna' and to conduct a second experiment to see if similar control is observed in three additional *Salvia* species.

Materials and methods

Experiment 1: On 23 April 2008, plugs (3.2 cm wide hex × 4.4 cm deep) were transplanted into 15.2 cm (1.3 L vol.) azalea pots using a peat-based substrate which contained 45 % peat moss, 10 % perlite, 15 % vermiculite, and 30 % bark (Fafard® 4P, Conrad Fafard Inc., Anderson, SC). Plants were fertigated with 150 mg L^{-1} N of 15N-2.1P-12.5K (Excel® 15-5-15 Cal-Mag, Scotts, Marysville, OH). Greenhouse air temperature day/night set points were 24/18 °C (75/65 °F) and the plants were grown under natural photoperiod and irradiance. On 7 May (14 DAP), BA foliar sprays at concentrations of 0, 100, 200, 400, 800 or 1600 mg L^{-1} were applied at a volume of 0.5 gal./100 ft^2. The experiment was a completely randomized design with five single-plant replications. On 22 May (28 DAP), data were collected on height (H, as measured from the top of the pot to the top of the plant), width [at the widest point (W1) and at 90° from that point (W2)], average diameter [(W1+W2) / 2], growth index (W1*W2*H), number of flowers and buds, number of branches, and number of nodes per unit height. Plants were rated for signs of phytotoxicity which included leaf chlorosis, necrosis, and cupping. At first flowering, plant height, number of buds, flower stalks, and days until flowering were recorded. Data were subjected to analysis of variance using the generalized linear model (PROC GLM) of SAS (SAS Institute, Cary, NC). Means were separated by pair-wise testing using Fisher's least significant differences (LSD) at $P \leq 0.05$.

Experiment 2: Plugs of *Salvia* × 'Ultra Violet', Ultra Violet sage (128 round cell size [cell measured 3 cm deep x 3 cm x 3 cm]); Salvia Marcus®, dwarf blue sage (72 square cell size [cell measured 4 cm deep x 4 cm x 4 cm]); and *S.* × *sylvestris* 'May Night' (72 square cell size [cell measured 4 cm deep x 4 cm x 4 cm]) were transplanted on 4 June 2010 into 15.24 cm diameter plastic pots (1.2 L vol.) containing Fafard® 4P (Fafard, Anderson, SC) substrate. Plants were fertilized at each irrigation with 150 mg L^{-1} N using 15N-2.1P-12.5K (Excel® 15-5-15 Cal-Mag, Scotts, Marysville, OH). Greenhouse air day/night set point temperatures were 26/21 ºC (80/70 ºF), respectively. The plants were grown under natural photoperiod and irradiance.

Foliar sprays of BA at 0, 125, 250 and 500 mg L^{-1} were applied 13 DAP using a volume of 0.5 gal./100 ft^2. The experiment was a

completely randomized design with 10 single-plant replications. Plant height (measured from the pot rim to the uppermost part of the tallest inflorescence), number of flowering shoots, and date of flowering were recorded.

Statistical analysis: Data for plant height were tested for each cultivar separately with ANOVA by general linear model (SAS Institute, Cary, NC). Plant height and date of bloom were regressed using the PROC REG procedure to determine the best-fit linear or quadratic model for the BA foliar spray. Terms of the models were judged to be significant or nonsignificant and included in the final model based on a comparison of F values at $\alpha \leq 0.05$.

Results and discussion

Experiment 1: At 28 DAP, plant growth was significantly affected with the application of BA. Plant height was >60 % shorter with BA ≥400 mg L^{-1}, average diameter was >17 % smaller with ≥200 mg L^{-1}, and growth index was >41% less with ≥100 mg L^{-1} as compared with the control (Table 1). The greatest effects on plant growth occurred with 1600 mg L^{-1} BA, but leaf phytotoxicity occurred. BA controlled the average internode length as measured by the number of nodes per unit height. BA at 400 mg L^{-1} produced 71 % more nodes per unit height when compared with the control. The application of BA delayed the onset of flower development with 85 to 92 % less flowers being present with ≥100 mg L^{-1} as compared with the control.

Table 1. Effect of benzyladenine (BA) on the growth characteristics of *Salvia nemorosa* 'Caradonna' at 28 days after potting

BA (mg L^{-1})	Height (cm)	Average diameter (cm)	Growth index	Nodes per unit height (cm)	Flowers and buds present
0	39.3 a[z]	25.9 a	24244 a	0.31 a	5.0 a
100	23.1 bc	24.9 ab	14308 b	0.51 bc	0.4 b
200	29.0 ab	21.6 bc	12819 b	0.41 ab	0.8 b
400	15.8 cd	20.3 cd	6659 c	0.53 bcd	0.2 b
800	12.4 cd	19.1 cd	4528 c	0.57 cd	0.0 b
1600	11.8 d	17.5 d	3666 c	0.67 d	0.0 b
P value	0.0001	0.0005	< 0.0011	0.0011	0.0039

[z] Means separated within columns by Fisher's LSD at $P \leq 0.05$.

Table 2. Effects of benzyladenine (BA) on the flowering characteristics of *Salvia nemorosa* 'Caradonna'. Data measured on each plant when the first inflorescence opened

BA Treatment (mg L^{-1})	Height at first flower (cm)	Days to first flower	Bolting shoots at first flower	Buds at first flower
0	54.7 a[z]	24.4 a	2.0 a	1.0 a
100	43.4 b	37.8 bc	4.8 ab	1.6 a
200	40.8 bc	33.4 ab	3.6 a	2.8 ab
400	36.1 c	43.2 cd	7.0 bc	5.2 b
800	35.3 c	45.6 cd	7.8 cd	5.2 b
1600	34.1 c	49.4 d	10.1 d	5.0 b
P-value	< 0.001	0.001	< 0.001	0.0396

[z] Means separated within columns by Fisher's LSD.

Height control continued through flowering. Plant height was reduced at first flower by 21 % at 100 mg L^{-1} and 34 % at 400 mg L^{-1} when compared with the untreated control (Table 2). When compared with the untreated control, BA at concentrations ≥400 mg L^{-1} delayed flowering by >19 days, produced more flowers; at least 350 % more bolting shoots and at least 520% more flower buds per plant when the first flower opened.

Experiment 2: The concentrations of BA used in this study had no effect on *Salvia* 'Ultra Violet' (Table 3). BA concentrations ≥ 125 mg L^{-1} resulted in significantly more flower spikes for *Salvia* 'May Night' (Table 3) and increased the number of flowering spikes until 61 DAP (Table 4). There was no significant difference in plant height among treatments (Table 3). Banko and Stefani (1991) found that applying 250 mg L^{-1} BA to *S. farinacea* (mealy sage) controlled height and increased branching with just one application, while Grossman *et al.* (as cited by Latimer and Whipker, 2010) found that a concentration of 300 mg L^{-1} applied to plugs of *Salvia* 'May Night' 34 DAP had increased basal branching. In experiment 1, we found that 100 to 800 mg L^{-1} of BA induced lateral branching. It is possible that because we did not spray BA during the plug stage, we missed the opportunity to obtain maximum results.

Salvia 'Marcus'® plants that bloomed 52 DAP were significantly less wide than those plants that bloomed at 41 and 46 DAP, but there were no differences in plant height and number of spikes.

Table 3. Responses of *Salvia* 'Ultra Violet', 'May Night' and Marcus® to foliar treatments of benzyladenine (BA)

BA (mg·L^{-1})	Cultivar								
	'Ultra Violet'			'May Night'			Marcus®		
	Height (cm)	Width (cm)	Spikes	Height (cm)	Width (cm)	Spikes	Height (cm)	Width (cm)	Spikes
0	28.1 a[z]	23.3 a	7.2 a	32.6 a	39.6 ab	3.7 b	54.7 a	53.8 ab	5.0 a
125	30.0 a	21.9 a	8.3 a	37.2 a	36.3 bc	5.4 a	50.8 a	54.8 a	4.5 a
250	27.0 a	22.1 a	7.4 a	32.9 a	42.4 a	6.0 a	55.8 a	54.7 a	6.0 a
500	30.5 a	24.3 a	9.1 a	32.0 a	32.3 c	5.3 a	50.1 a	46.5 b	5.5 a

[z]Means from 10 replications followed by different letters indicate a significant difference between growth features for each BA treatment at the *P*=0.05 level.

Table 4. Height, width, and number of flowering spikes measured on bloom date (number of days after potting) after applications of four benzyladenine (BA) foliar spray concentrations to *Salvia* 'Ultra Violet', 'May Night' and Marcus® growing in 15.2 cm diameter pots

Bloom date	Cultivar								
	'Ultra Violet'			'May Night'			Marcus®		
	Height (cm)	Width (cm)	Spike number	Height (cm)	Width (cm)	Spike numbe	Height (cm)	Width (cm)	Spike numbe
41	28.9[z]	22.9	8	34.9 a	36.5 c	4.4 c	50.4 a	52.8 a	4.5 a
46	nb	nb	nb	39.5 a	46.0 a	4.5 bc	52.9 a	56.0 a	5.9 a
48	nb	nb	nb	nb	nb	nb	55.6 a	49.0 ab	6.0 a
52	nb	nb	nb	nb	nb	nb	41.0 a	41.0 b	5.5 a
56	nb	nb	nb	31.8 a	37.1 bc	5.6 b	nb	nb	nb
61	nb	nb	nb	32.3 a	49.3 a	7.5 a	nb	nb	nb

[z]Means from 10 replications followed by different letters indicate a significant difference for that growth parameter between flowering dates at the *P*=0.05 level. nb- No growth measurements are indicated because plants were not in bloom on those dates.

Plants blooming at 52 DAP were 22 and 27 % narrower than plants that bloomed on 41 and 46 DAP, respectively (Table 4).

Foliar sprays of BA at 400 to 800 mg L^{-1} can be used to improve *Salvia* 'Caradonna' plant quality by controlling height and average internode length. Foliar sprays of BA resulted in plants with a more compact appearance, but they delayed the onset of flowering. Ultimately, flowering was increased during the production cycle with BA. However, once flowering initiated, BA increased the number of blooms. Hoover *et al.* (1998) and Latimer (personal communications) reported that BA foliar sprays also delayed shoot growth of *Hosta* by two to three weeks due to the increase in offshoot number, which resulted in more robust plants. Therefore, growers will have to determine if the additional three weeks in production time is worth the trade-off of having shorter plants with 350 percent increase in the number of flowers.

Our results with BA in the second experiment on the three additional *Salvia* species 'Ultra Violet', 'May Night', and Marcus® did not provide the same level of positive results as with 'Caradonna'. This result indicates that *Salvia* species will have to be evaluated individually for their response to BA.

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