

Report Submitted to Fine Americas, Inc.

**Evaluation of
Chlormequat and Daminozide Products
on Greenhouse Crops**

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OBJECTIVE

The objective of this experiment was to compare the relative efficacy of the plant growth retardants Citadel (chlormequat, Fine Americas, Inc.), Dazide (daminozide, Fine Americas, Inc.), Cycocel (chlormequat, OHP, Inc.), and B-Nine (daminozide, OHP, Inc.) on four species of bedding plants.

EXPERIMENTAL METHODS

Plant Material

On 11 April 2007, one 288-cell plug tray each of blue salvia (*Salvia farinacea* 'Blue Bedder'), celosia (*Celosia plumosa* 'Fresh Look Red'), geranium (*Pelargonium* 'Floever Violet'), and verbena (*Verbena* 'Obsession Lilac New') was received from Raker's Acres (Litchfield, MI) and placed in a controlled temperature chamber at Michigan State University (MSU). Plants were received 7 to 10 days after germination and were subsequently grown at 68 °F (20 °C) under a 16-hour photoperiod and an average daily light integral (DLI) of 9 to 11 mol·m⁻²·d⁻¹ provided by cool-white fluorescent and incandescent lamps.

When plants were deemed ready for transplant, geranium and salvia (24 April) and celosia and verbena (30 April) were transplanted into 4.5 inch (11.5-cm, 600-mL volume) round plastic containers filled with a commercial soilless medium composed of Canadian sphagnum peat, horticultural vermiculite, and perlite (Suremix; Michigan Grower Products, Inc., Galesburg, MI). Plants were subsequently grown in a greenhouse environment as described below.

Chemical Applications

The chemical applications were made 7 or 8 days after transplant. On the day of application, plants were randomly assigned to 13 treatments containing nine or ten plants each. A single foliar spray of B-Nine, Citadel, Cycocel, Dazide, Dazide + Citadel, or B-Nine + Cycocel at a volume of 2 quarts/100 ft² was made between 10:00 and 11:00 am on the day of application for each treatment according to the experimental protocol (Table 1). For each species, a group of plants that were not treated with any plant growth retardant were designated as the control. A surfactant was not included in any of the chemical applications.

Table 1. Plant growth retardants and application rates used on all species of bedding plants. Chemicals were applied as a single foliar spray at a volume of 2 quarts/100 ft².

Plant growth retardant	Foliar spray rate
Dazide	2500 ppm
B-Nine	2500 ppm
Dazide	5000 ppm
B-Nine	5000 ppm
Citadel	1000 ppm
Cycocel	1000 ppm
Citadel	1500 ppm
Cycocel	1500 ppm
Dazide + Citadel	2500 + 1500 ppm
B-Nine + Cycocel	2500 + 1500 ppm
Dazide + Citadel	5000 + 1000 ppm
B-Nine + Cycocel	5000 + 1000 ppm

Greenhouse Environment

After transplant, plants were grown in a glass-glazed greenhouse with fan-and-pad cooling at MSU. The temperature set point in the greenhouse was a constant 68 °F and the actual average air temperature was 72.1 ±4.3 °F (22.3 ±2.4 °C). Plants were grown under a 16-hour photoperiod and under an average DLI of 17.8 mol·m⁻²·d⁻¹.

Data Collection

Measurements

Plant height was measured on the date of the chemical application and at 2 and 4 weeks after the application and height increases were calculated. The total height increase was calculated by subtracting the initial plant height from the height 4 weeks after the spray applications. For all species, plant height was measured from the medium surface to either the tip of the most recently unfolded leaf on the main stem or to the base of the tallest flower bud on the main stem, whichever was greatest.

Date of first flowering was recorded for each plant, and time to flower was calculated. On the date that each plant flowered, the number of open flowers and flower buds, and plant height, were recorded. First flowering was determined when salvia had 3 or 4 floral whorls on an inflorescence with an open flower; for celosia when the inflorescence at the shoot apex reached 4 cm in length; for geranium when one inflorescence had 3 or 4 open flowers; and for verbena when one inflorescence had 3 open flowers. In all species except celosia, plant height at flowering was measured from the medium surface to the base of the open flower. In celosia, plant height was measured from the medium surface to the top of the inflorescence.

Photographs

Photographs of all species were taken at 2 and 4 weeks after application. Photographs depicting leaf burn on geranium and salvia were taken 2 weeks after application. See the PowerPoint presentation included with this report.

Data Analysis

A completely randomized design was used. Data were analyzed using SAS's mixed model and general linear model procedures and pairwise comparisons between treatments were performed using Tukey's honestly significant difference (HSD) test at $P \leq 0.05$.

RESULTS

Celosia plumosa 'Fresh Look Red'

At 2 weeks after application, all chemical treatments inhibited stem elongation by 1.1 to 2.7 cm compared to untreated plants (Figure 1). There were no differences between application rates for each chemical. For example, stem elongation was similar among plants treated with Citadel at 1000 ppm and 1500 ppm. At 4 weeks after application, daminozide treatments suppressed stem elongation by 3.0 to 4.7 cm, chlormequat chloride suppressed elongation by 5.2 to 7.7 cm, and the combination of the chemicals inhibited stem extension by 9.6 to 10.0 cm. Plants treated with Dazide + Citadel or B-Nine + Cycocel were less than half the height of control plants when measured 4 weeks after the applications.

Plants treated with 2500 ppm Dazide + 1500 ppm Citadel flowered a mean of 11 days later than control plants (Table 2). There were no significant differences among treatments in the number of inflorescences or plant height at flowering.

Pelargonium 'Floever Violet'

At 1 week after application, plants treated with Citadel or Cycocel alone, Dazide + Citadel, or B-Nine + Cycocel displayed a phytotoxicity response on the leaf margins, creating a chlorotic leaf margin (Table 3). These symptoms were similar to previous studies with the application of Cycocel on geranium. The chlorosis on leaf margins decreased over time and symptoms were slightly apparent a 4 weeks after application. At 2 weeks after application, stem elongation varied among treatments and there were no apparent differences between control plants and those treated with any chemical (Figure 2). At 4 weeks after application, plants treated with Citadel or Cycocel at 1000 ppm or 1500 ppm were a mean of 2.2 cm shorter than control plants. Application of daminozide did not have any retarding effect on geranium, regardless of formulation.

There were no differences in time to flower among any treatments. The number of inflorescences at first flower was not significantly different among treatments and ranged from 6.4 to 8.2 (Table 3). Plants treated with Citadel at 1000 ppm, Citadel or Cycocel at 1500 ppm, or Dazide + Citadel and B-Nine + Cycocel were a mean of 2.6 cm shorter at flower than control plants.

Salvia farinacea 'Blue Bedder'

The cultivar 'Blue Bedder' has a tall habit (>50 cm at flower) and height control is required during commercial production to inhibit stem extension. At 1 week after application, we observed symptoms of phytotoxicity on $\geq 50\%$ of plants treated with Citadel or Cycocel alone or Dazide + Citadel (Table 4). The phytotoxicity was displayed

as a pale yellow burn on the leaf margins of a couple leaves per plant and persisted until the end of the experiment. Although the chlorosis on leaf margins never completely faded, there was no decrease of aesthetic quality.

At 2 weeks after the chemical application, all treatments except Dazide at 2500 ppm suppressed stem elongation (Figure 3). Plants treated with Dazide + Citadel or B-Nine + Cycocel had the greatest height suppression and plants were a mean of 7.5 cm shorter than control plants when measured 2 weeks after the treatments. At 4 weeks after application, there were no significant differences in plant height among control plants and those treated with Dazide or B-Nine alone. However this may be because of the large variability in plant height. In all other treatments, plant height at 4 weeks was a mean of 17.0 to 27.0 cm shorter than control plants.

Plants treated with 2500 ppm B-Nine + 1500 Cycocel or 5000 ppm Dazide + 1000 ppm Citadel flowered a mean of 10 days later than control plants (Table 4). There were no significant differences in the number of inflorescences among treatments. Final plant height at flower ranged from 45.4 to 63.8 cm and there were no significant trends among treatments, likely because of the variability in plant height within the population.

***Verbena* ‘Obsession Lilac New’**

Stem elongation at 2 weeks after application was suppressed by a mean of 3.5 cm in plants treated with Dazide + Citadel at both rates and 2500 ppm B-Nine + 1500 Cycocel (Figure 4). There were no statistical differences in height among any other treatments and control plants at 2 weeks. At 4 weeks after application, plant height was similar among treatments and there were no significant differences compared to control plants. Therefore, the inhibitory effects of daminozide and chlormequat chloride are more transient on verbena than on the other three crops that were studied.

Time to flower was delayed by a mean of 3 days in plants treated with 2500 ppm B-Nine + 1500 Cycocel or 5000 ppm Dazide + 1000 ppm Citadel (Table 5). The number of inflorescences at first open flower ranged from 10.6 to 12.8 and there were no significant trends among treatments. Plants treated with Dazide + Citadel at both rates were a mean of 2.3 cm shorter at flowering than control plants.

CONCLUSIONS

These results indicate the effectiveness of chlormequat and daminozide at controlling stem elongation in celosia ‘Fresh Look Red’, geranium ‘Floever Violet’, salvia ‘Blue Bedder’, and verbena ‘Obsession Lilac New’ varied with active ingredient and species. For celosia, all treatments except B-Nine at 2500 ppm were effective at suppressing stem elongation even at 4 weeks after application; however at flower (29 to 41 days after application), none of the chemical treatments were still effective. For geranium, Dazide or B-Nine were not effective at inhibiting stem extension, whereas treatments containing chlormequat chloride were effective at controlling plant height at flower (9 weeks after application). For blue salvia, all treatments except Dazide at 2500 ppm controlled plant height at 2 weeks after application, but at 4 weeks, only treatments containing

chlormequat chloride were still effective. For verbena, 2500 ppm Dazide + 1500 Citadel and 5000 ppm Dazide + 1000 Citadel were the most effective treatments at suppressing stem elongation at 2 weeks after application and at flower, but their effect was not apparent 4 weeks after application.

In all species except verbena, there were no statistical differences in growth retardation between chemicals with the same active ingredient (e.g., Dazide vs. B-Nine or Citadel vs. Cycocel). For example, Citadel applied at 1500 ppm produced a similar response as Cycocel applied at 1500 ppm. For verbena, there was a significant difference ($P = 0.02$) in height control after 2 weeks between Dazide + Citadel and B-Nine + Cycocel.

Some chemical treatments delayed flowering by 3 to 11 days in celosia, salvia, and verbena. There were no differences in the number of flowers among any plant growth retardant treatments for all species.

We recommend that further studies be performed to determine the effects of Dazide and Citadel on other bedding plants.

Table 2. The effects of plant growth retardant treatments on time to flower, number of inflorescences at flowering, and plant height at flower in celosia (*Celosia plumosa* ‘Fresh Look Red’).

Plant growth retardant	Spray rate (ppm)	Time to flower (days)	Inflorescence number	Plant height at flower (cm)
Control	0	30 b ^z	22.2 a	26.7 a
Dazide	2500	31 b	25.9 a	25.7 a
B-Nine	2500	30 b	19.0 a	24.6 a
Dazide	5000	29 b	22.6 a	23.2 a
B-Nine	5000	29 b	19.9 a	22.2 a
Citadel	1000	36 ab	30.8 a	28.2 a
Cycocel	1000	32 b	17.5 a	23.7 a
Citadel	1500	36 ab	26.7 a	25.2 a
Cycocel	1500	36 ab	30.1 a	24.6 a
Dazide + Citadel	2500 + 1500	41 a	28.0 a	26.0 a
B-Nine + Cycocel	2500 + 1500	36 ab	26.3 a	22.5 a
Dazide + Citadel	5000 + 1000	37 ab	21.4 a	22.9 a
B-Nine + Cycocel	5000 + 1000	37 ab	19.8 a	24.1 a
Significance		***	NS	NS
Contrasts				
Dazide vs. B-Nine		NS	NS	NS
Citadel vs. Cycocel		NS	NS	NS
Dazide + Citadel vs. B-Nine + Cycocel		NS	NS	NS

^zWithin-column means followed by different letters are significantly different by

Tukey=s honestly significant difference (HSD) test at $P \leq 0.05$.

NS, *** Nonsignificant or significant at $P \leq 0.001$.

Table 3. The effects of plant growth retardant treatments on time to flower, number of inflorescences at flowering, plant height at flower, and leaf burn (chemical phytotoxicity) percentage in geranium (*Pelargonium* 'Floever Violet').

Plant growth retardant	Spray rate (ppm)	Time to flower (days)	Inflor. number	Plant height at flower (cm)	Leaf burn (%)
Control	0	37 a ^z	6.5 a	20.1 a	0
Dazide	2500	37 a	7.1 a	20.3 a	0
B-Nine	2500	37 a	6.4 a	19.5 ab	0
Dazide	5000	38 a	7.2 a	21.0 a	0
B-Nine	5000	37 a	6.7 a	21.4 a	0
Citadel	1000	39 a	7.6 a	17.3 c	90
Cycocel	1000	37 a	6.9 a	17.7 bc	100
Citadel	1500	38 a	7.0 a	16.7 c	100
Cycocel	1500	38 a	7.7 a	17.2 c	100
Dazide + Citadel	2500 + 1500	38 a	8.1 a	17.5 bc	100
B-Nine + Cycocel	2500 + 1500	38 a	8.2 a	17.6 bc	100
Dazide + Citadel	5000 + 1000	38 a	7.1 a	17.9 bc	70
B-Nine + Cycocel	5000 + 1000	38 a	7.5 a	17.5 bc	40
Significance		NS	NS	***	-- ^y
Contrasts					
Dazide vs. B-Nine		NS	NS	NS	--
Citadel vs. Cycocel		NS	NS	NS	--
Dazide + Citadel vs. B-Nine + Cycocel		NS	NS	NS	--

^zWithin-column means followed by different letters are significantly different by Tukey=s honestly significant difference (HSD) test at $P \leq 0.05$.

^yData not analyzed.

NS, *** Nonsignificant or significant at $P \leq 0.001$.

Table 4. The effects of plant growth retardant treatments on time to flower, number of inflorescences at flowering, plant height at flower, and leaf burn percentage (chemical phytotoxicity) in blue salvia (*Salvia farinacea* ‘Blue Bedder’).

Plant growth retardant	Spray rate (ppm)	Time to flower (days)	Inflor. number	Plant height at flower (cm)	Leaf burn (%)
Control	0	34 b ^z	14.5 a	59.3 ab	0
Dazide	2500	37 ab	16.1 a	63.8 a	0
B-Nine	2500	37 ab	15.7 a	53.0 ab	0
Dazide	5000	39 ab	12.8 a	57.8 ab	0
B-Nine	5000	36 ab	14.4 a	58.2 ab	0
Citadel	1000	36 ab	11.7 a	45.4 b	70
Cycocel	1000	38 ab	12.6 a	49.8 ab	100
Citadel	1500	39 ab	12.8 a	52.6 ab	90
Cycocel	1500	37 ab	11.8 a	46.3 b	90
Dazide + Citadel	2500 + 1500	39 ab	12.3 a	45.6 b	80
B-Nine + Cycocel	2500 + 1500	44 a	12.9 a	59.1 ab	40
Dazide + Citadel	5000 + 1000	44 a	12.5 a	53.1 ab	50
B-Nine + Cycocel	5000 + 1000	42 ab	13.7 a	51.5 ab	0
Significance		**	NS	***	-- ^y
Contrasts					
Dazide vs. B-Nine		NS	NS	NS	--
Citadel vs. Cycocel		NS	NS	NS	--
Dazide + Citadel vs. B-Nine + Cycocel		NS	NS	NS	--

^zWithin-column means followed by different letters are significantly different by Tukey=s honestly significant difference (HSD) test at $P \leq 0.05$.

^yData not analyzed.

NS, *, *** Nonsignificant or significant at $P \leq 0.05$, or 0.001, respectively.

Table 5. The effects of plant growth retardant treatments on time to flower, number of inflorescences at flowering, and plant height at flower in *Verbena* ‘Obsession Lilac New’.

Plant growth retardant	Spray rate (ppm)	Time to flower (days)	Inflorescence number	Plant height at flower (cm)
Control	0	17 c ^z	12.3 ab	11.5 ab
Dazide	2500	19 abc	12.8 ab	11.0 abc
B-Nine	2500	19 abc	15.4 a	12.4 a
Dazide	5000	19 abc	11.9 ab	11.0 abc
B-Nine	5000	19 abc	12.4 ab	10.9 abc
Citadel	1000	18 abc	10.6 b	10.1 abc
Cycocel	1000	18 abc	10.7 b	9.6 bc
Citadel	1500	18 abc	11.3 ab	9.7 bc
Cycocel	1500	17 bc	10.8 b	10.0 bc
Dazide + Citadel	2500 + 1500	19 abc	11.3 ab	9.2 c
B-Nine + Cycocel	2500 + 1500	20 a	11.3 ab	9.5 bc
Dazide + Citadel	5000 + 1000	20 a	11.4 ab	9.2 c
B-Nine + Cycocel	5000 + 1000	19 ab	12.4 ab	9.7 bc
Significance		***	*	***
Contrasts				
Dazide vs. B-Nine		NS	NS	NS
Citadel vs. Cycocel		NS	NS	NS
Dazide + Citadel vs. B-Nine + Cycocel		NS	NS	NS

^zWithin-column means followed by different letters are significantly different by Tukey=s honestly significant difference (HSD) test at $P \leq 0.05$.

NS, *, *** Nonsignificant or significant at $P \leq 0.05$ or 0.001, respectively.

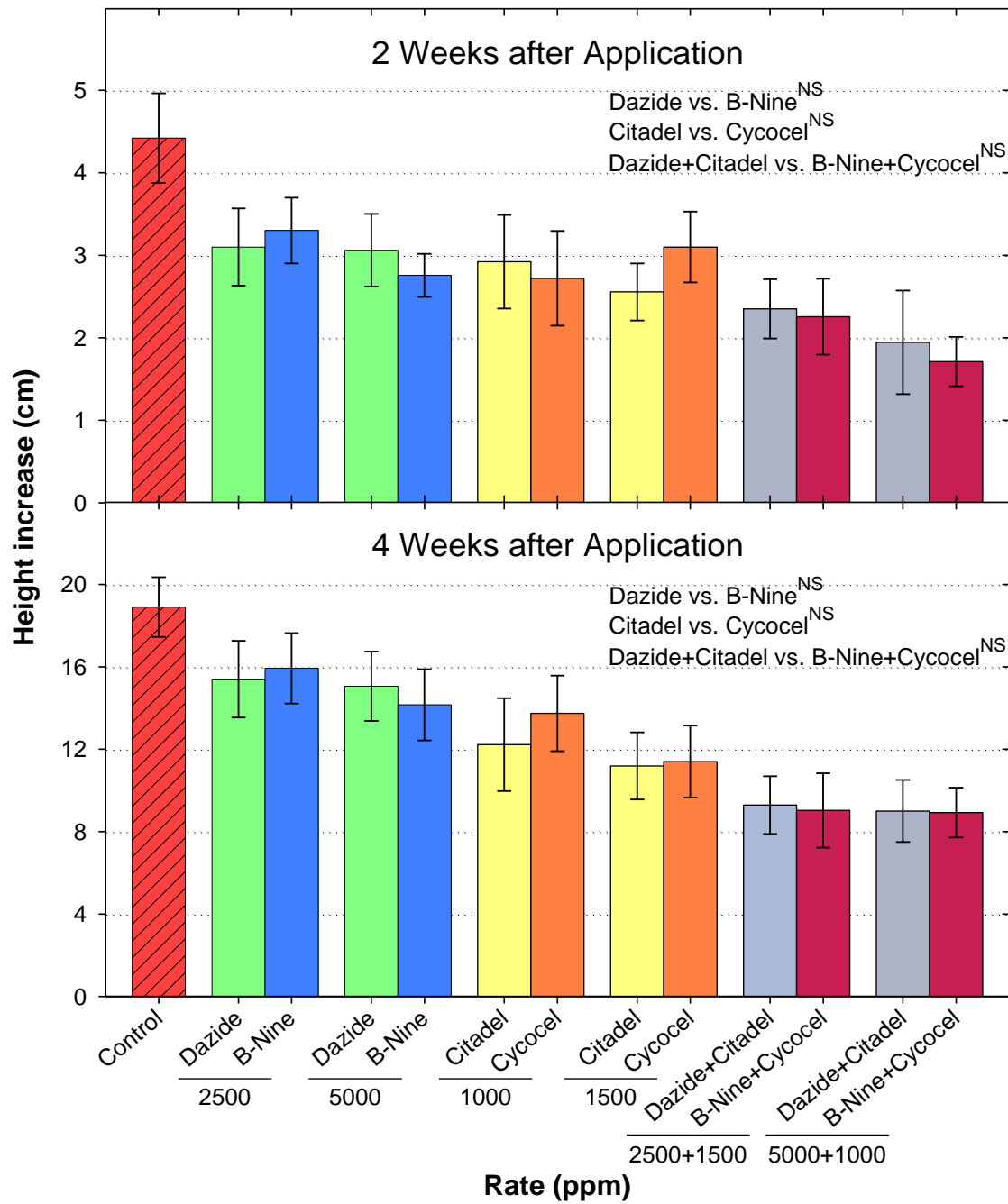


Figure 1. The effects of a single foliar spray of a plant growth retardant on plant height measured 2 and 4 weeks after application in *Celosia plumosa* ‘Fresh Look Red’. Error bars represent 95% confidence intervals. ^{NS}Nonsignificant.

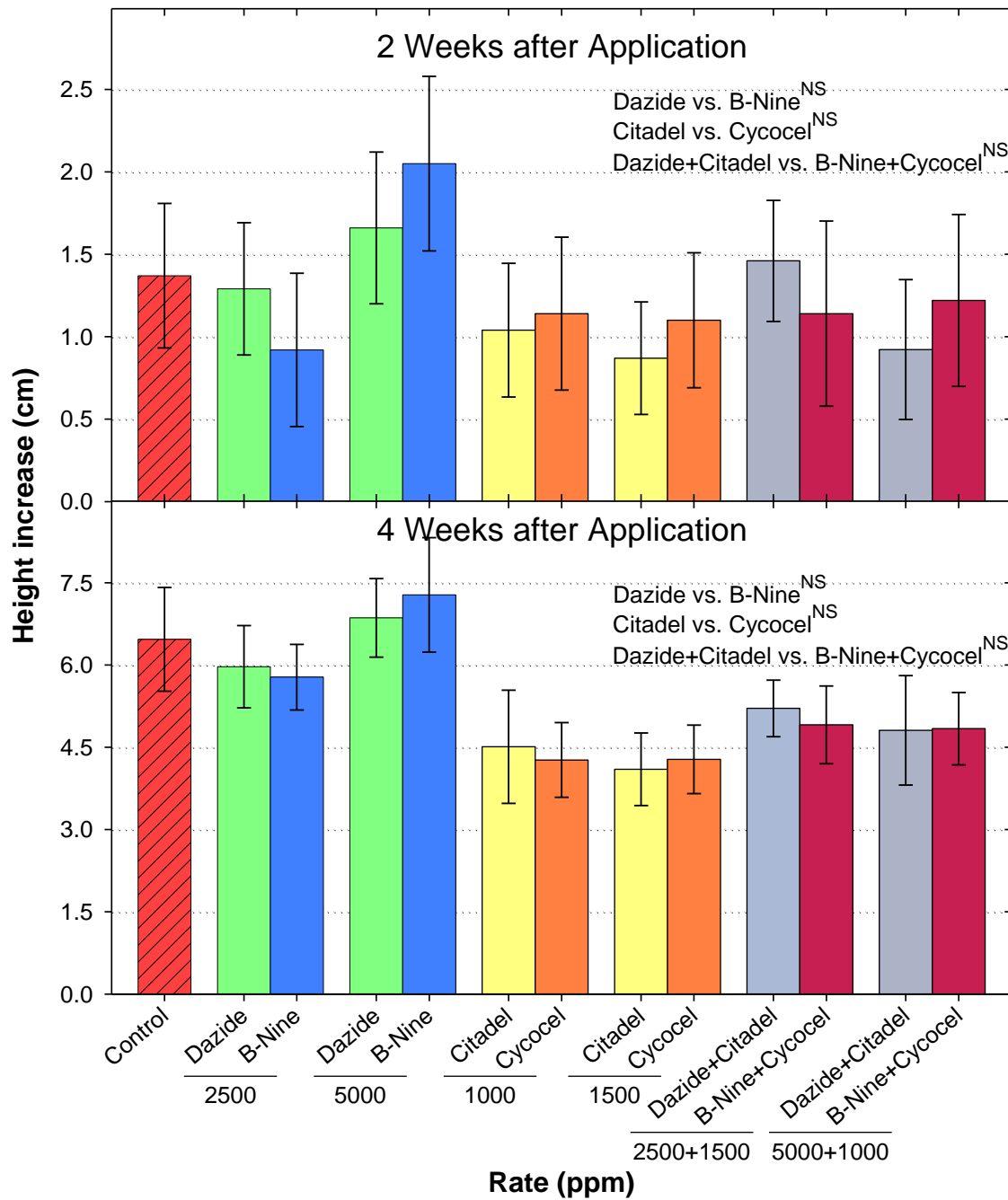


Figure 2. The effects of a single foliar spray of a plant growth retardant on plant height measured 2 and 4 weeks after application in *Pelargonium* ‘Floever Violet’. Error bars represent 95% confidence intervals. ^{NS}Nonsignificant.

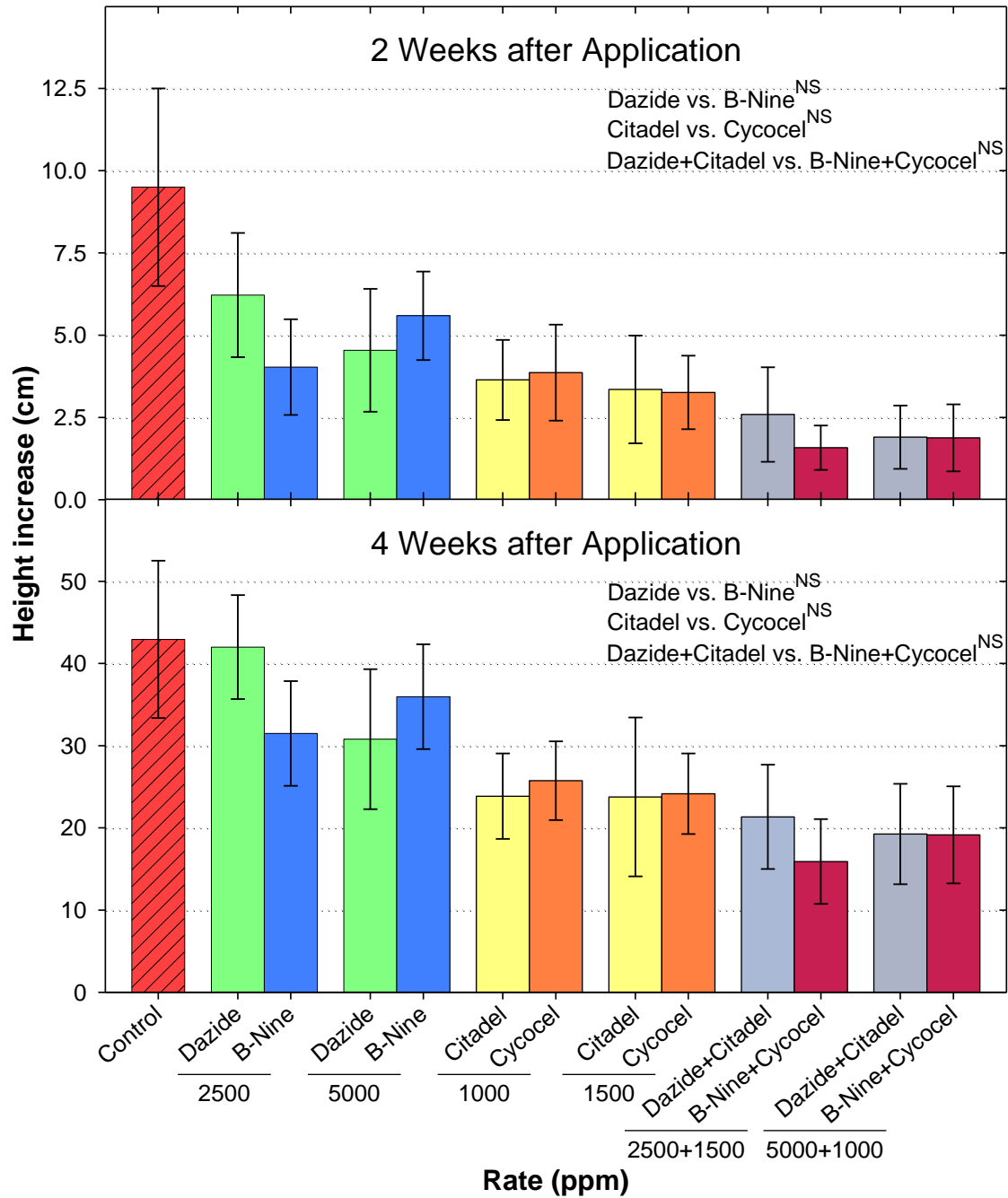


Figure 3. The effects of a single foliar spray of a plant growth retardant on plant height measured 2 and 4 weeks after application in *Salvia farinacea* 'Blue Bedder'. Error bars represent 95% confidence intervals. ^{NS} Nonsignificant.

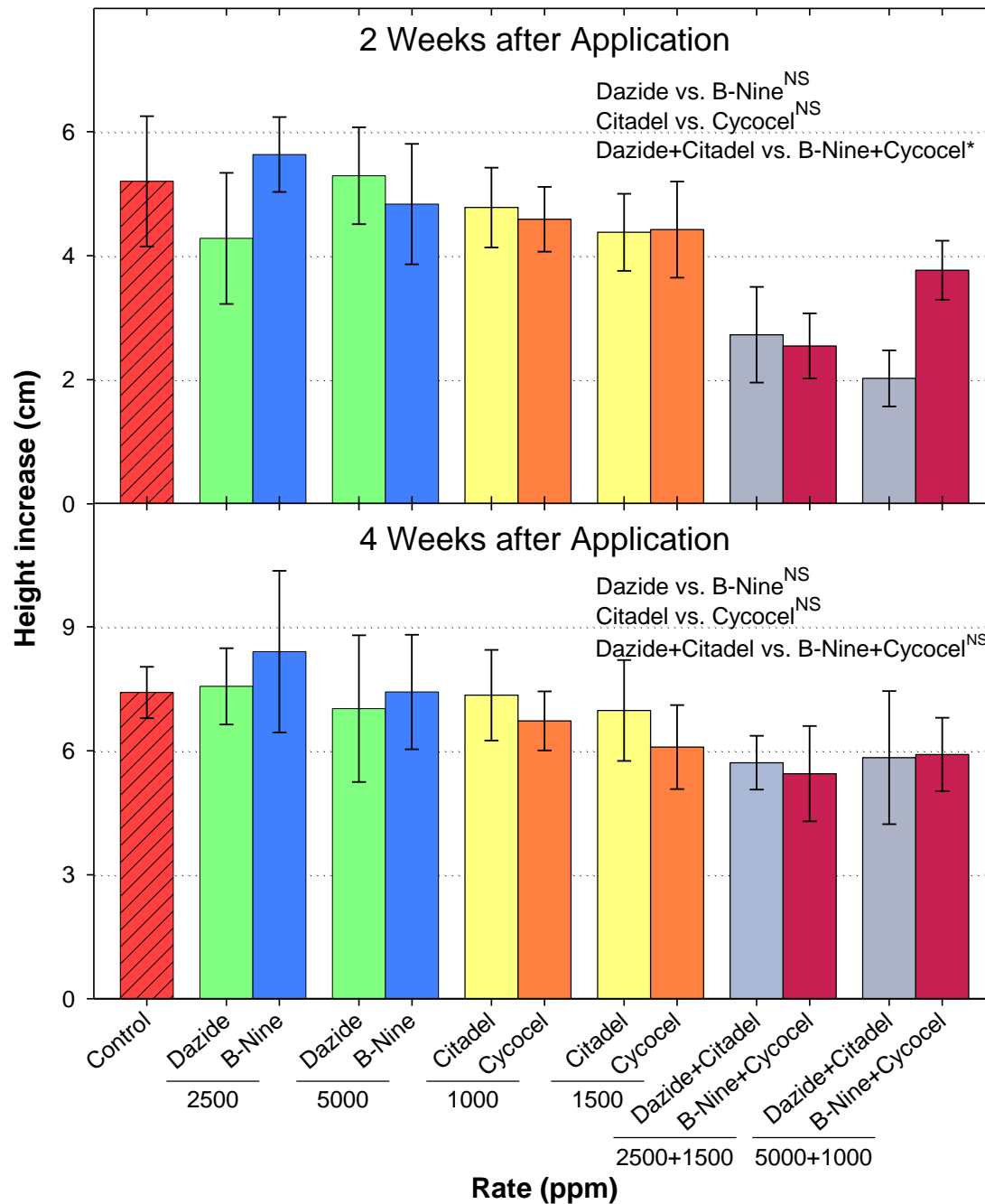


Figure 4. The effects of a single foliar spray of a plant growth retardant on plant height measured 2 and 4 weeks after application in *Verbena* ‘Obsession Lilac New’. Error bars represent 95% confidence intervals. ^{NS}, *Nonsignificant or significant at $P \leq 0.05$.