Chemical Promotion of Branching and Stem Elongation of Poinsettia

Jennifer Kalinowski[1], Iftikhar Ahmad[1], and John M. Dole[1]

Keywords. bract expansion, cytokinins, dikegulac sodium, *Euphorbia pulcherrima*, gibberellins, height control

Abstract. Growers have traditionally used mechanical pinching and other cultural practices to control height and encourage branching for full and uniform poinsettia (*Euphorbia pulcherrima*) plants. A total of six experiments were conducted over 5 years to evaluate the impact of chemically treating poinsettia on final height, branching, first color, visible bud formation, and anthesis. The first four experiments evaluated the potential of benzyladenine (BA) and gibberellins [$GA_{(4+7)}$] to increase height of treated poinsettia. Timing of the application was assessed during Expt. 1 using a combined concentration of 3 ppm BA and 3 ppm $GA_{(4+7)}$ applied at 5, 7, 9, or 11 weeks after pinching; some cultivars exhibited significantly more elongated inflorescences when treatment occurred 7 or 9 weeks after pinching. The application method and frequency was assessed during Expt. 2, and treatments were applied one or three times with either drench application at a concentration of 2 ppm or foliar application at a concentration of 5 ppm or untreated controls. All plants treated with three drench applications produced taller plants on average than when only applied once or when treated with a foliar application. Expt. 3 further assessed height gain and effects on flowering during late-season production with foliar applications of BA+$GA_{(4+7)}$ applied 2 weeks after first color at a concentration of 2 ppm compared with untreated control plants. One cultivar, Mars Red, was observed to have a significant decrease in days to anthesis when treated (9 days) compared with untreated plants, but no cultivars exhibited a significant change in height resulting from treatment. Expt. 4 assessed both the application method (foliar and drench) and change in final environment when plants were either maintained in a greenhouse or relocated to a postharvest room before anthesis. Most cultivars experienced a significant height increase when treated with foliar application of BA+$GA_{(4+7)}$ regardless of the final environment, but a significant delay in days to first color, visible bud, and anthesis was prevalent, and only one cultivar exhibited a treatment benefit from drench application with no significant delay in flowering or differences caused by changing environment. Expts. 5 and 6 were conducted over 2 growing years to evaluate the benefits of chemically pinching poinsettia using dikegulac sodium at a concentration of 800 ppm applied either once or twice (1 week apart) or 1600 ppm applied once to promote branching. The tallest plants were those treated one time at a concentration of 800 ppm showing lack of dominance in the apical meristem. The greatest number of shoots occurred when plants were treated with 800 ppm twice, whereas one application of 800 or 1600 ppm often, but not always, resulted in more shoots compared with mechanically pinched plants. Interestingly, the increased number of shoots from treated plants was often more than double the number compared with mechanical pinching, but those additional shoots failed to develop, which resulted in only one or two additional inflorescences. Production time was found to be a tradeoff because most dikegulac sodium-treated plants experienced an increased number of days to first color, visible bud, and/or anthesis. These results demonstrate that height control, whether to encourage stem elongation or halt apical dominance, is cultivar-specific, and that although both the method and concentration may be determined uniformly on some cultivars, the timing of application is crucial because of potential delays in floral development.

In its native environment, poinsettia (*Euphorbia pulcherrima*) grows as a weak shrub or small tree with narrow bracts that can reach 3 to 4 m (Trejo et al. 2012). Commercial growers have been able to capitalize on years of plant breeding and introduction of refined cultivars with shorter, fuller, and more visually appealing plants possessing intense colors of orange, pink, light green, white, and the hallmark holiday reds in the bracts. These attributes have made poinsettia one of the most economically important potted plants sold in the United States, with wholesale sales of more than $157 million (US Department of Agriculture, National Agricultural Statistics Service 2021).

Poinsettia are greenhouse-grown under exacting horticultural practices to produce crops of uniform size and quality with height tolerances dictated by both marketing and shipping factors (Fisher et al. 1996). Stem height often can be controlled by pinching, cultural practices, or plant growth regulators (PGRs) applied as a foliar spray or a drench. PGRs are commonly used to prevent excessive poinsettia stem elongation (Ecke et al. 2004). Currey and Lopez (2011) demonstrated that when applied early in the season, PGRs such as triazoles can be effective in regulating shoot growth and height suppression of poinsettia when applied as a drench and absorbed through the root system.

Unfortunately, the application of PGRs is not exact and can result in plants that are too short (Latimer and Whipker 2012). To promote stem elongation in poinsettia, a combination of BA, a synthetic cytokinin, and GA_{4+7} can be useful for recovering height from overapplication of PGRs. However, excess stem elongation can cause a delay in flowering and formation of weak shoots on the plant (Bergmann et al. 2017).

Traditionally, poinsettia have been pinched to remove apical dominance and allow the lower nodes to branch out. This results in a wider and fuller plant, but mechanical pinching is labor-intensive and may not be economically feasible in high-density production (Latimer and Whipker 2012). Additionally, pinching in some cultivars can result in poor branching or failure to produce lateral shoots (Faust and Heins 1996), and it can negatively affect flowering, with inflorescences developing below the bract canopy when the pinch is not properly executed (Berghage et al. 1989). Cultural practices affecting light (Liu and Heins 2002; Mata and

Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
0.3048	ft	m	3.2808
2.54	inch(es)	cm	0.3937
16.3871	$inch^3$	cm^3	0.0610
1	ppm	$mg \cdot L^{-1}$	1
0.001	ppm	$mL \cdot L^{-1}$	1000
(°F − 32) ÷ 1.8	°F	°C	(°C × 1.8) + 32

Botto 2009), temperature (Berghage and Heins 1991; Faust and Heins 1996), water deficit (Alem et al. 2015), and nutrition (Latimer and Whipker 2012; Scoggins and Mills 1998) can also be manipulated to alter vegetative growth rate and branching pattern.

Dikegulac sodium is a metabolic inhibitor used in foliar applications that chemically pinches the plant by causing meristematic death and the promotion of lateral branching. A secondary benefit is that treated plants may require less fertilizer and water than pinched plants as plant growth is halted until new growth begins (Latimer and Whipker 2012). Lateral shoot length, tertiary shoot number (shoots in the leaf axils of secondary shoots), visual appearance, and quality of poinsettia cultivars have exhibited varied responses to the use of dikegulac sodium (Dunn et al. 2021; Padhye et al. 2008).

The objectives of this research were to discern best practices of timing, concentration, and method of application using BA+$GA_{(4+7)}$ to increase plant height, evaluate the optimum concentration and number of applications needed when using dikegulac sodium to chemically pinch poinsettia, and assess the potential effects on flowering and vegetative growth of poinsettia when using these PGRs.

Materials and methods

Expt. 1 (year 1). Rooted cuttings of 12 poinsettia cultivars (Table 1) were transplanted on 13 Aug. Plants were mechanically pinched on 4 Sep, leaving six to seven nodes on each plant.

Foliar sprays were applied with 1:1 BA+$GA_{(4+7)}$ (Fascination; Valent Biosciences Corp., Libertyville, IL, USA) at a concentration of 3 ppm plus a nonionic surfactant (Capsil; Aquatrols, Paulsboro, NJ, USA) at 0.5 $mL \cdot L^{-1}$. Plants were treated at 5 weeks (8 Oct), 7 weeks (22 Oct), 9 weeks (5 Nov), or 11 weeks (19 Nov) after pinch or were untreated controls. Solutions were applied such that the foliage was covered, but the solution was not yet running off. There were three replicates per treatment.

Data collected at anthesis included plant height (taken from the bench to the tallest point on the plant), plant diameter (an average of two individual measurements of plant width, one perpendicular to the other, on each replicate plant), bract width (taken from three representative bracts at the widest point of the bract), and inflorescence elongation [length from lowest bract (at least partially colored) to tip of uppermost cyathia], days to first color (days to first appearance of interveinal red color on bracts), and days to anthesis (determined by the presence of pollen). A randomized complete block design with factorial arrangement (chemical treatment, cultivar) was used.

Expt. 2 (year 2). Rooted cuttings of three poinsettia cultivars (Table 1) were transplanted on 19 Aug and mechanically pinched on 10 Sep, leaving six to seven nodes on each plant. Plants were maintained as previously described.

Treatments consisted of BA+$GA_{(4+7)}$ foliar application at a concentration of 5 ppm 2 weeks after pinch and weekly until three applications were completed, drench application at a concentration of 2 ppm 2 weeks after pinch and weekly until three applications were completed, one foliar application at a concentration of 5 ppm 2 weeks after pinch, one drench application at a concentration of 2 ppm 2 weeks after pinch, or untreated controls. There were five replicates per treatment. Data collected at anthesis included plant height, diameter, days to first color, and days to anthesis. Data from each cultivar and treatment were analyzed in the same manner as that for Expt. 1.

Expt. 3 (year 2). Rooted cuttings of seven poinsettia cultivars (Table 1) were transplanted, maintained, and pinched in unison with Expt. 2.

Plants were treated with one foliar spray application of BA+$GA_{(4+7)}$ at a concentration of 2 ppm ~1 week after first color for each cultivar (15 Oct for Christmas Feelings; 16 Oct for Mira Red and Premium Red; 18 Oct for Christmas Beauty; 23 Oct for Enduring Red; and 30 Oct for Mars Red and Solstice) or served as untreated controls. There were six replicate plants per cultivar; half were treated and half served as untreated controls. Data collected were days to first color and at anthesis included plant height, bract diameter, and days to anthesis. Data from each cultivar and treatment were analyzed in the same manner as Expt. 1.

Expt. 4 (year 3). Rooted cuttings of three poinsettia cultivars (Table 1) were transplanted 18 Aug and pinched on 12 Sep, leaving six to seven nodes on each plant. Plants were maintained as previously described.

Plants were treated with BA+$GA_{(4+7)}$ foliar spray applications at a concentration of 5 ppm plus nonionic surfactant at 0.5 $mL \cdot L^{-1}$ applied four times (1 week after pinch, 2 weeks after pinch, at first color, and 2 weeks after first color), or BA+$GA_{(4+7)}$ drench applications at a concentration of 2 ppm applied three times (2 weeks after pinch, at first color, and 2 weeks after first color), or untreated controls. There were 10 replicate plants per treatment group. Half of each treatment group, including tap water control plants, were transferred to a postharvest environment (maintained at a 20 ± 2 °C, 40% to 60% relative humidity, 12-h photoperiod at 15 $\mu mol \cdot m^{-2} \cdot s^{-1}$) ~2 weeks before the anthesis date, with the remainder of plants maintained in the greenhouse. Data collected were height at 30 d, height at 60 d, final height at anthesis, plant diameter at anthesis, growth index at anthesis [(plant diameter 1 + plant diameter 2 + height) ÷ 3], days to first color, days to visible bud, and days to anthesis. Data from each cultivar and treatment were analyzed in the same manner as previously described.

Expts. 5 and 6 (years 4 and 5). Rooted cuttings of six poinsettia cultivars (Table 1) were used in both experiments. Expt. 5 plants were transplanted on 17 Aug and Expt. 6 plants were transplanted the following year on 13 Aug, as previously described. Plant maintenance followed the same protocol as the previous experiments during years 1 to 4. Untreated control plants from Expt. 5 were pinched on 6 Sep, and untreated control plants in Expt. 6 were pinched on 29 Aug.

Treatments for both experiments consisted of foliar sprays of dikegulac sodium (Augeo; OHP Inc., Mainland,

Received for publication 12 Jan 2023. Accepted for publication 29 Mar 2023.

Published online 3 May 2023.

[1]Department of Horticultural Science, North Carolina State University, 2721 Founders Drive, Raleigh, NC 27695-7609, USA

We gratefully acknowledge Dümmen Orange, Syngenta, Selecta, and Beekenkamp for providing poinsettia cuttings and Ingram McCall for poinsettia production.

J.M.D. is the corresponding author. E-mail: jmdole@ncsu.edu.

https://doi.org/10.21273/HORTTECH05186-23

Table 1. Poinsettia cultivars used for six experiments conducted over five growing years to evaluate response to plant growth regulator treatment. Rooted cuttings were obtained from Beekenkamp (Maasdijk, The Netherlands), Dummen Orange (Columbus, OH, USA), Selecta (West Chicago, IL, USA), and Syngenta (Gilroy, CA, USA).

	$BA+GA_{(4+7)}$[i]				Dikegulac sodium	
Cultivar	Expt. 1 / Yr 1 13 Aug to 24 Nov[ii]	Expt. 2 / Yr 2 19 Aug to 7 Dec	Expt. 3 / Yr 2 19 Aug to 8 Dec	Expt. 4 / Yr 3 18 Aug to 14 Dec	Expt. 5 / Yr 4 17 Aug to 17 Dec	Expt. 6 / Yr 5 13 Aug to 17 Dec
Advent Red	×					
Christmas Angel	×					
Christmas Beauty			×			
Christmas Eve	×					
Christmas Feelings	×		×			
Cortez Early	×					
Early Glory	×					
Enduring Red			×			
Infinity Red	×					
Jubilee Red		×		×	×	×
Mars Red	×		×	×		
Mira Red			×			
Neva Red						×
Noel Red					×	×
Orion Red	×					
Premium Red	×		×	×		
Prestige Early	×	×				
Prestige Red	×	×			×	×
Prima Red					×	×
Solstice			×			
Stargazer Red					×	×
Titan Red					×	

[i] $BA+GA_{(4+7)}$ = benzyladenine plus gibberellin.
[ii] Date when plants were transplanted to the date when all plants had reached anthesis for each experiment.

PA, USA) at a concentration of 800 ppm applied 10 d after transplant, 1600 ppm applied 10 d after transplant, or 800 ppm applied 10 d after transplant with an additional 800 ppm applied 7 d later, or plants were pinched to mimic mechanical production, leaving six to seven nodes on the plant. Five replicate plants per cultivar were used within each treatment group. Data collected at anthesis included plant height, diameter, growth index [(plant diameter 1 + plant diameter 2 + height) ÷ 3], shoot number, dominant shoot number (only Expt. 6), number of inflorescences (shoots with cyathia and associated bracts, only Expt. 5), fresh weight and dry weight (only Expt. 6), days to first color, days to visible bud formation, and days to anthesis. Data from each cultivar, year, and treatment were analyzed in the same manner as previously described.

Plant maintenance. Rooted cuttings of all cultivars used in each of the six experiments were transplanted into a peat-based, soilless substrate (Fafard 4P; Conrad Fafard, Agawam, MA, USA) in green plastic, azalea-style, 6 1/2 × 4 5/8-inch (volume, 105 $inch^3$) pots (The HC Companies, Middlefield, OH, USA). Plant maintenance included fertilization with each irrigation through microtubes with 150 $mg \cdot L^{-1}$ N liquid fertilizer (20N–4.4P–16.6K or 15N–0P–12.5K for pH control as needed) (Everris, Dublin, OH, USA), temperature set points of 24/18 °C day/night, and natural daylength in a glass greenhouse.

Data analysis. Data from each experiment were analyzed and separately subjected to an analysis of variance using the Generalized Linear Models procedure and statistical software (SAS version 9.4; SAS Institute Inc., Cary, NC, USA). Means separation tests were implemented using Tukey's honestly significant difference test with $P \leq 0.05$ for significant interactions and main effects.

Results

Expt. 1 (year 1). Cultivars varied in their response to timing of the $BA+GA_{(4+7)}$ application. Inflorescences were significantly more elongated when treated at 7 weeks for 'Christmas Feelings' and 'Mars Red' by 3.8 and 10.7 cm, respectively, when compared with the control, but not for 'Christmas Eve' or 'Cortez Early' (Table 2). 'Premium Red' had significantly more elongated (by 2.2 cm) inflorescences after the 9-week treatment compared with control plants. Plant diameter was significantly larger (by 5.4 cm) after 5-week treatment applications for 'Cortez Early' compared with 11-week treatments. Additionally, bract width was significantly larger for 'Christmas Eve' poinsettia after the 7-week treatment compared with the 5-week treatment (11.7 and 9.7 cm, respectively). No significant delays were identified in days to first color or anthesis for any of the treatment application times or cultivars when compared with the control plants (data not presented). Application of $BA+GA_{(4+7)}$ did not influence any measure parameters of 'Advent Red', 'Christmas Angel', 'Early Glory', 'Infinity Red', 'Orion Red', 'Prestige Early', and 'Prestige Red' plants in this experiment (data not presented).

Table 2. Response to early-season and late-season application of benzyladenine and gibberellins [BA+$GA_{(4+7)}$] to enhance height of five poinsettia cultivars (Expt. 1). Plants were transplanted on 13 Aug and mechanically pinched on 4 Sep. Plants were either untreated (control) or treated with foliar applications of a 1:1 ratio of BA+$GA_{(4+7)}$ at a concentration of 3 ppm (3 $mg \cdot L^{-1}$) plus a nonionic surfactant at 0.5 $mL \cdot L^{-1}$ (500 ppm) 5 weeks after pinching (8 Oct), 7 weeks after pinching (22 Oct), 9 weeks after pinching (5 Nov), or 11 weeks after pinching (19 Nov).

Application (weeks)	Plant diam (cm)[i]	Bract width (cm)	Inflorescence ht (cm)
	Christmas Eve		
Control	40.5	10.9 ab[ii]	6.0
5	39.4	9.7 b	6.7
7	38.2	11.7 a	7.3
9	40.0	11.0 ab	6.0
11	37.4	10.9 ab	6.8
Significance[iii]	NS	*	NS
	Christmas Feelings		
Control	44.0	11.2	6.3 b
5	45.7	10.8	8.6 ab
7	44.6	11.5	10.1 a
9	46.7	10.9	7.7 ab
11	41.1	10.7	7.5 ab
Significance	NS	NS	*
	Cortez Early		
Control	43.9 ab	11.9 b	5.8
5	47.8 a	12.1 ab	6.1
7	47.0 ab	11.6 b	7.4
9	45.0 ab	13.0 a	6.0
11	42.4 b	11.6 b	5.3
Significance	*	**	NS
	Mars Red		
Control	48.3	10.7	7.2 b
5	49.6	10.7	7.9 b
7	48.5	10.0	10.7 a
9	48.0	9.8	6.9 b
11	50.3	10.4	7.3 b
Significance	NS	NS	**
	Premium Red		
Control	35.8	10.2	5.3 b
5	35.4	10.4	6.2 ab
7	36.8	10.8	6.3 ab
9	37.6	10.9	7.5 a
11	36.8	10.7	4.8 b
Significance	NS	NS	**

[i] 1 cm = 0.3937 inch.
[ii] Means within each cultivar in a column followed by the same letter are not significantly different.
[iii] Significance between treatments is indicated within columns for each individual cultivar and dependent variable. NS, *, ** nonsignificant or significant at $P < 0.05$ or 0.01, respectively.

Expt. 2 (year 2). Application method and frequency were only significant for 'Prestige Red' poinsettia ($P < 0.05$) when BA+$GA_{(4+7)}$ was applied three times via drenches (44.4 cm) compared with untreated controls (40.3 cm). All other treatments were intermediate in height (data not presented). The application of BA+$GA_{(4+7)}$ did not influence other measured parameters (diameter, days to first color, and days to anthesis) for 'Prestige Red' or any measure parameters of 'Jubilee Red' or 'Prestige Early' plants in this experiment (data not presented).

Expt. 3 (year 2). Late-season foliar application of BA+$GA_{(4+7)}$ had no significant effect on plant height or bract diameter between treated and untreated poinsettia within or among any of the tested cultivars (data not presented). However, a significant difference was observed among cultivars in days to first color (Fig. 1A). For instance, 'Enduring Red', 'Mars Red', and 'Solstice' required a significantly longer time to reach first bract color (59, 66, and 65 d, respectively) compared with all other cultivars.

Additionally, 'Mars Red' and 'Solstice' poinsettia required significantly longer to reach anthesis than all other cultivars, but 'Enduring Red' reached anthesis significantly sooner independent of any treatment effect (Fig. 1B). Interestingly, untreated controls of 'Christmas Feelings' and 'Mira Red' plants had similar days to anthesis as untreated controls of 'Mars Red'; however, after receiving treatment, time to anthesis was significantly shorter for both cultivars by 9 d.

Expt. 4 (year 3). The application method and final environment had a significant effect on most cultivars evaluated. Foliar application of BA+$GA_{(4+7)}$ resulted in significantly taller plants regardless of environment the last 2 weeks before anthesis for 'Jubilee Red', 'Mars Red', and 'Prestige Red' poinsettia (Table 3). The final height of 'Jubilee Red' poinsettia treated with foliar sprays was ~2.6 cm taller on average when moved to a postharvest room before anthesis compared with foliar-treated plants maintained in the greenhouse, and it was 9.5 cm taller than untreated controls also moved to the postharvest room. 'Jubilee Red' experienced a significant delay in days to first color (4 d), visible bud (8 d), and anthesis (16 d) with the foliar application method compared with untreated plants maintained in a greenhouse. When plants were relocated to the postharvest room, the delay in anthesis (8 d) was similar to that of plants treated by the foliar method and maintained in a greenhouse, but not significantly different from that of control and drenched plants moved to a postharvest room.

'Mars Red' and 'Prestige Red' poinsettia treated with foliar sprays were slightly taller (2.6 and 3.6 cm, respectively) when maintained in the greenhouse compared with plants moved to the postharvest room, and significantly taller (9.8 and 9.1 cm,

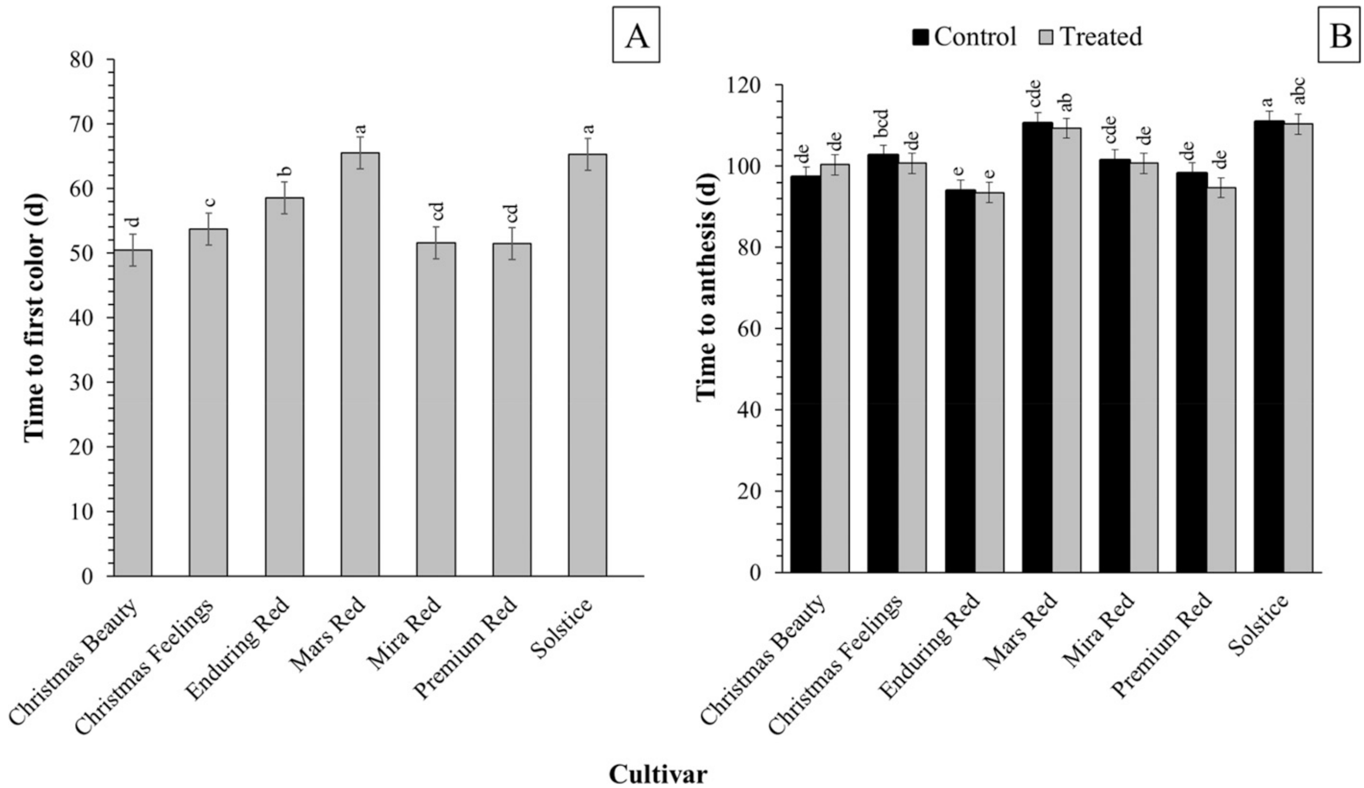

Fig. 1. Response of seven poinsettia cultivars to foliar sprays of benzyladenine and gibberellins [$BA+GA_{(4+7)}$] to increase plant height in late-season production (Expt. 3). Plants were potted 19 Aug and pinched 10 Sep, leaving six to seven nodes on each plant. Treatments were administered ~1 week after first color for each cultivar (15 Oct for Christmas Feelings; 16 Oct for Mira Red and Premium Red; 18 Oct for Christmas Beauty; 23 Oct for Enduring Red; and 30 Oct for Mars Red and Solstice) or served as untreated controls. (A) Average days to first color for each cultivar. Lowercase letters designate significant differences among cultivars in days to first color based on Tukey's honestly significant difference test at $P > 0.05$. For each cultivar, data were pooled across treatment, which was not significantly different. (B) Average days to anthesis for both treated and untreated plants across cultivars. Mean interaction effects among cultivars followed by the same lowercase letter are not significantly different based on Tukey's honestly significant difference test at $P > 0.05$. Interval bars represent *SE* constructed using one *SE* from each mean.

respectively) than untreated controls maintained in the greenhouse (Table 3). Interestingly, the foliar treatments resulted in less of a delay in first color than the controls or drenches by 16 and 17 d, respectively, for 'Mars Red' when maintained in the greenhouse and when moved to the postharvest room by 10 and 10 d, respectively. However, there was a significant increase in days to first visible bud for this cultivar when treated with foliar sprays (13 d) compared with drenches: 15 d longer than the untreated control plants when maintained in a greenhouse and similar delays of 12 and 12 d, respectively, when plants were moved to the postharvest room. The delay in anthesis was similar between treated 'Mars Red' poinsettia that were maintained in the greenhouse, but it was significantly longer (9 d) for foliar sprays compared with drenches when moved to the postharvest room 2 weeks before anthesis. Similar delays in days to first color, visible bud, and anthesis were observed for foliar-sprayed 'Prestige Red' plants in either environment, but the delay in anthesis was significantly greater (7 d) when foliar-sprayed plants were maintained in the greenhouse compared with those moved to the postharvest environment 2 weeks before anthesis.

Alternatively, the drench application of $BA+GA_{(4+7)}$ proved more beneficial for 'Premium Red' plants, which were significantly taller than untreated controls by 10.2 cm in either environment (Table 3). However, final plant height was statistically similar between both treatment methods in either environment for this cultivar. There was no significant delay in days to first color or visible bud for any of the treated 'Premium Red' plants compared with untreated controls. Drenched plants maintained similar days to anthesis as untreated controls, but foliar-treated plants exhibited a significant delay in anthesis when moved to the postharvest environment compared with drenched plants (10 d) and untreated controls (12 d).

The growth index was variable among cultivars and was dependent on the $BA+GA_{(4+7)}$ application method and final environment. The growth index was significantly greater for 'Jubilee Red' poinsettia when treated with foliar applications and moved to a postharvest room (5.2 cm) compared with both drench applications and untreated controls, but it was similar to that of treated and untreated plants that were maintained in a greenhouse (Table 3). The growth index was greater for 'Prestige Red' among all treatments and environments when plants were treated with foliar sprays, but it was significantly more (4.5 cm) when maintained in a greenhouse

Table 3. Response to application method using benzyladenine and gibberellins [BA+GA$_{(4+7)}$] to increase height and change in environment before anthesis on four poinsettia cultivars (Expt. 4). Plants either served as untreated controls or were treated with BA+GA$_{(4+7)}$ foliar sprays applied four times: 1 week after pinching, 2 weeks after pinching, at first color, and 2 weeks after first color), or drenches [2 ppm (2 mg·L^{-1}) applied three times, 2 weeks after pinching, at first color, and 2 weeks after first color]. One half of each of the treatments was transferred to a postharvest evaluation room ~2 weeks before anthesis. Plants were potted 18 Aug and pinched on 8 Sep, allowing six to seven nodes to remain.

Location	Application method	Ht at 30 d (cm)[i]	Ht at 60 d (cm)	Final ht (cm)	Plant diam (cm)	Growth index (cm)	First color (d)	Visible bud (d)	Anthesis (d)
				Jubilee Red					
Greenhouse	None	12.0 ab[ii]	21.0 b	25.4 b	35.5	32.1 b	62 b	80 b	96 c
	Spray	14.4 ab	26.2 a	32.4 a	36.2	34.9 ab	67 a	88 a	112 a
	Drench	12.8 ab	22.2 b	27.2 b	35.4	32.7 b	62 b	81 b	101 bc
Postharvest room	None	11.5 b	20.5 b	25.5 b	35.4	32.1 b	63 b	80 b	100 bc
	Spray	15.0 a	29.0 a	35.0 a	38.4	37.3 a	66 a	88 a	108 ab
	Drench	12.8 ab	21.2 b	26.8 b	34.7	32.1 b	62 b	80 b	105 abc
Significance[iii]		*	***	***	NS	**	***	***	***
				Mars Red					
Greenhouse	None	14.4 b	20.8 b	26.6 c	39.0	34.9	66 a	86 b	108 b
	Spray	20.2 a	34.0 a	36.4 a	33.7	34.6	50 b	100 a	116 a
	Drench	15.0 b	23.8 b	29.8 bc	39.2	36.1	67 a	88 b	112 ab
Postharvest room	None	14.2 b	21.6 b	25.6 c	38.1	33.9	68 a	86 b	110 b
	Spray	19.8 a	32.6 a	33.8 ab	38.3	36.8	57 b	98 a	116 a
	Drench	14.0 b	24.6 b	28.2 c	34.9	32.7	67 a	85 b	108 b
Significance		***	***	***	NS	NS	***	***	***
				Premium Red					
Greenhouse	None	14.0 c	23.4 d	25.0 b	34.4	31.3 b	51	73	88 c
	Spray	16.4 abc	29.0 bc	29.8 ab	36.7	34.4 ab	53	73	97 ab
	Drench	17.2 abc	35.2 a	35.2 a	40.4	38.7 a	52	73	90 bc
Postharvest room	None	14.8 bc	24.6 cd	25.0 b	33.8	30.9 b	51	73	92 bc
	Spray	18.2 a	30.2 b	30.6 ab	37.8	35.4 ab	53	73	104 a
	Drench	18.0 ab	35.2 a	35.2 a	39.4	38.0 a	51	73	94 bc
Significance		**	***	***	NS	***	NS	NS	***
				Prestige Red					
Greenhouse	None	14.4	21.6 b	26.6 c	37.8 b	34.1 bc	63 b	80 b	97 c
	Spray	17.8	28.6 a	36.0 a	43.6 a	41.1 a	69 a	88 a	116 a
	Drench	17.0	23.4 b	28.6 c	39.2 ab	35.7 bc	65 b	81 b	98 c
Postharvest room	None	14.6	21.8 b	25.2 c	36.0 b	32.4 c	63 b	80 b	100 c
	Spray	17.2	27.0 a	32.4 b	38.7 ab	36.6 b	69 a	89 a	109 b
	Drench	16.2	24.0 b	26.2 c	35.7 b	32.5 c	64 b	81 b	99 c
Significance		NS	***	***	**	***	***	***	***

[i] 1 cm = 0.3937 inch.
[ii] Means within each cultivar in a column followed by the same letter are not significantly different.
[iii] Significance between treatments is indicated within columns for each individual cultivar and dependent variable; NS, *, **, *** nonsignificant or significant at $P <$ 0.05, 0.01, or 0.001, respectively.

compared with plants moved to a postharvest room. Alternatively, the growth index for 'Premium Red' was similar between treated plants in either environment, but plants treated with drenches had a significantly ($P <$ 0.001) greater growth index than untreated plants when maintained in the greenhouse (7.4 cm) or moved to the postharvest room (7.1 cm). Growth indices of 'Mars Red' poinsettia were statistically similar. Effects on plant diameter were only significant ($P < 0.01$) for 'Prestige Red' poinsettia treated with foliar applications (5.8 cm) when maintained in a greenhouse compared with the untreated controls in that same environment (Table 3).

Expts. 5 and 6 (years 4 and 5). The application frequency of dikegulac sodium affected vegetative growth of all cultivars. In both growing years, the tallest plants were treated with only one application of 800 ppm, showing lack of control on the apical stem (Tables 4 and 5, personal observation). Additionally, in both growing years, plants that were treated with two applications of 800 ppm 1 week apart had a significant increase in shoot number for all cultivars except Stargazer Red in year 5 (Tables 4 and 5, Fig. 2). However, most additional shoots remained below the canopy, and only one to two additional inflorescences were observed compared with the pinched control plants (Fig. 3). In both experiments, plants treated with two applications of 800 ppm or one application of 1600 ppm were statistically similar in height to mechanically pinched control plants (Tables 4 and 5) except for 'Jubilee Red' and 'Noel Red' in Expt. 2 (Table 5). 'Jubilee Red' and 'Noel Red' were significantly shorter (3.6 and 2.6 cm, respectively) than the mechanically pinched controls when treated at a concentration of 800 ppm in two applications and 2.9 cm shorter when treated with 1600

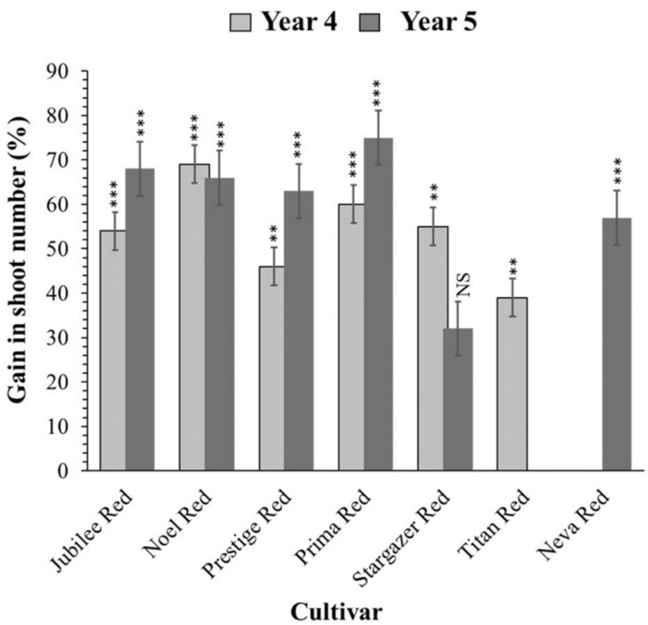

Fig. 2. Percent increase in the shoot number for poinsettia cultivars Jubilee Red, Noel Red, Prestige Red, Prima Red, Stargazer Red, Titan Red, and Neva Red when treated with two foliar applications of dikegulac sodium in comparison with the mechanically pinched control plants during each of two growing years (Expt. 6). The concentration of the application was 800 ppm (800 mg·L^{-1}), with the first treatment applied 10 d after transplant and the second application 7 d later. In year 4, plants were transplanted 17 Aug; in year 5, they were transplanted 13 Aug. Significance level based on Tukey's honestly significant difference test ($P \leq 0.05$). NS, **, * = nonsignificant or significant at $P < 0.01$, or $P < 0.001$, respectively. Interval bars represent *SE* constructed using one *SE* from each mean.**

ppm in one application for 'Noel Red' (Table 5). The application of dikegulac sodium did not influence plant diameter or plant growth index for any cultivar (data not presented).

However, the application of dikegulac sodium delayed first color, visible bud formation, and anthesis, with the greatest effect in year 5 (Tables 4 and 5). The number of days to first color was significantly longer for 'Noel Red', 'Prestige Red', and 'Titan Red' in year 4 (Table 4), and it was significantly longer for all cultivars in year 5 (Table 5). The cultivar most affected in year 5 was Neva Red, with 1600 ppm delaying first color by 7 d, visible bud by 10 d, and anthesis by 20 d (Table 5). The cultivar least affected was Prestige Red (Expt. 6), with 1600 ppm delaying first color by 2 d, visible bud by 5 d, and anthesis by 8 d (Table 5). 'Noel Red' experienced the greatest effect on floral development (year 4) from either two applications of 800 ppm or one application of 1600 ppm, with delays in first color (4 and 6 d), visible bud formation (6 and 7 d), and anthesis (8 and 7 d), respectively (Table 4). One foliar application at 1600 ppm or two foliar applications at 800 ppm resulted in greater shoot numbers for 'Jubilee Red', with an additional 5 and 7 shoots, respectively, and for 'Prima Red', with an additional 7 and 9 shoots, respectively, with no significant impact on days to anthesis in year 4 (Table 4).

Fig. 3. Visual reference of poinsettia cultivar Prestige Red. (A) Mechanically pinched control plants depicting seven lateral shoots and scar where pinch occurred with no formation of additional inflorescences. (B) Plants treated with dikegulac sodium twice at a concentration of 800 ppm (800 mg·L^{-1}) 1 week apart depicting 11 distinct shoots and additional inflorescences formed inside the canopy.

Discussion

When using BA+GA$_{(4+7)}$, growers should be wary of the potential formation of weak shoots, delay in first bract color, and malformation of cyathia, as observed with some plants across cultivars in this study. Blanchard and Runkle (2008) demonstrated the importance of timing in treatment application; it was determined that as plants mature, the potential to increase height decreases. At 30 d after first color, there was little or no promotion of stem elongation, but later application had a greater effect on bract expansion. This supports results obtained in Expt. 1; plants treated 7 or 9 weeks after the pinch had more elongated inflorescences and greater bract size for some cultivars.

In the current study, application of BA+GA$_{(4+7)}$ had a significant effect on all cultivars evaluated, particularly the height response of 'Premium Red' when the drench method was applied and the ability of the plants to maintain timely development of bract color even after one application. Conversely, Bergmann et al. (2017) showed that high concentrations of BA+GA$_{(4+7)}$ on 'Renaissance Red' poinsettia resulted in significantly longer days to first bract color and anthesis. This is concurrent to delays in first color in this study of cultivars Mars Red and Prestige Red with foliar applications and some delay in anthesis observed across most cultivars. We noted for every 1-inch increase in

Table 4. Response to dikegulac sodium application for chemical pinching versus mechanical pinching in six poinsettia cultivars (Expt. 5). Plants were either mechanically pinched 20 d after transplant (6 Sep) or treated with foliar application sprays of dikegulac sodium at a concentration of 800 ppm 10 d after transplanting (27 Aug), 1600 ppm 10 d after transplanting, or 800 ppm 10 d after transplanting with a second application 7 d later (3 Sep). Mechanically pinched plants served as controls and were left with six to seven nodes on each plant.

Concn (ppm)/ applications (no.)[i]	Ht (cm)[i]	Shoots (no.)	Inflorescences (no.)	First color (d)	Visible bud (d)	Anthesis (d)
			Jubilee Red			
Pinched	37.6	6.0 c[ii]	4.8 ab	61	68	95 ab
800/1	37.8	9.0 b	4.4 b	60	67	93 b
1600/1	35.6	11.0 ab	5.4 ab	62	69	99 a
800/2	35.8	13.0 a	6.0 a	61	68	94 ab
Significance[iii]	NS	***	*	NS	NS	*
			Noel Red			
Pinched	35.1	7.7 c	5.4	59 b	71 b	99 b
800/1	35.6	15.7 b	5.2	60 ab	73 ab	100 ab
1600/1	33.4	20.7 ab	6.2	65 a	78 a	106 a
800/2	34.3	25.0 a	6.6	63 ab	77 a	107 a
Significance	NS	***	NS	*	**	**
			Prestige Red			
Pinched	36.1 b	6.7 c	4.6 ab	66 b	70	95
800/1	38.6 a	10.0 ab	4.2 b	67 b	69	94
1600/1	37.3 ab	9.3 bc	5.6 a	68 ab	73	99
800/2	35.6 b	12.3 a	5.8 a	70 a	72	99
Significance	**	**	**	**	NS	NS
			Prima Red			
Pinched	38.6	7.3 c	5.0 b	60	72	99
800/1	39.6	12.3 b	5.8 b	61	73	101
1600/1	38.4	14.7 ab	6.0 ab	59	72	100
800/2	38.6	18.3 a	7.2 a	62	71	101
Significance	NS	***	**	NS	NS	NS
			Stargazer Red			
Pinched	36.6	7.3 b	5.2 b	59	72 b	100
800/1	40.1	11.0 ab	6.8 a	61	76 ab	103
1600/1	37.6	14.0 a	6.4 ab	63	77 a	105
800/2	38.1	16.3 a	5.8 ab	63	74 ab	102
Significance	NS	**	*	NS	*	NS
			Titan Red			
Pinched	36.3	7.3 b	5.2 b	51 b	63 b	84 b
800/1	38.4	11.3 a	5.4 b	52 b	64 b	84 b
1600/1	35.6	11.0 a	5.2 b	59 a	67 a	90 a
800/2	36.8	12.0 a	6.6 a	56 a	65 ab	86 ab
Significance	NS	**	***	***	**	**

[i] 1 ppm = 1 $mg \cdot L^{-1}$, 1 cm = 0.3937 inch.
[ii] Means within each cultivar down a column followed by the same letter are not significantly different.
[iii] Significance between treatments is indicated within columns for each individual cultivar and dependent variable; NS, *, **, *** nonsignificant or significant at $P < 0.05$, 0.01, or 0.001 respectively.

plant height, flowering was delayed 5 to 6 d for ‘Jubilee Red’, 2 d for ‘Mars Red’, and ~5 d with foliar application of $BA+GA_{(4+7)}$ (data not presented). However, drench treatments delayed flowering less than 1 d for ‘Premium Red’ and ‘Prestige Red’, but ‘Prestige Red’ was delayed more (3–5 d) when treated with foliar application (Table 3).

Bergmann et al. (2017) also noted that treated plants had more leaves per stem at the onset of short days and anthesis than untreated controls, suggesting that plants grew taller by producing more internodes rather than having greater internode lengths. Internode length was not evaluated in the current study, but observations of increased growth index of cultivars such as Jubilee Red and Premium Red warrant further investigation. Therefore, assessments of additional poinsettia cultivars would be beneficial to determining cultivar-specific effects when treating with $BA+GA_{(4+7)}$.

Previous research has shown that growth and development of poinsettia can be affected by cultural practices and environment. Goreta et al. (2008) showed that differences in the vegetative growth rate of poinsettia attributable to cultural practices such as shoot thinning and pot size were dependent on cultivar. In the current study, a striking increase in shoot number with the use of dikegulac sodium was observed and found to be most substantial for ‘Noel Red’. Many of the plants in this study treated with dikegulac sodium exhibited phytotoxicity within 3 weeks of application; however, by 6 weeks, most plants demonstrated satisfactory recovery and had minimal visual symptoms, with an evident increase in branching (personal observation). Most cultivars were observed to have an increase in shoot number from year to year, which may be caused by an earlier pinching date in year 5.

Research conducted by Dunn et al. (2021) demonstrated that dikegulac sodium applications on ‘Orange Spice’ in conjunction with pinching increased lateral shoot length; however, when applied in combination with unpinched plants, there was also an increase in tertiary shoot number, improving the visual appearance and quality of the plants. Similarly, Padhye et al. (2008) demonstrated that the branching response of ‘Freedom Red’ resulted in an increase in tertiary shoots when treated with BA or $BA+GA_{(4+7)}$ foliar applications. However, at flowering, bracts covered the additional shoots; therefore, increased branching did not improve visual quality compared with nontreated control plants (Padhye et al. 2008). Although, in the current study, plants treated with dikegulac sodium had more lateral branches than pinched controls, most substantially for Prima Red in year 2 (Fig. 2), most of the additional lateral shoots remained below the canopy, and the average increase in inflorescence number was only one to two for most cultivars, as seen with Prestige Red (Fig. 3).

Table 5. Response to dikegulac sodium application for chemical pinching versus mechanical pinching in six poinsettia cultivars (Expt. 6). Plants were either mechanically pinched 16 d after transplant (29 Aug) or treated with foliar application sprays of dikegulac sodium at a concentration of 800 ppm 10 d after transplant (23 Aug), 1600 ppm 10 d after transplant, or 800 ppm 10 d after transplant with a second application 7 d later (30 Aug). Mechanically pinched plants served as controls and were left with six to seven nodes on each plant.

Concn (ppm)/ applications (no.)[i]	Final ht (cm)[i]	Diam (cm)	Growth index (cm)	Shoots (no.)	Dominant shoots (no.)	Fresh wt (g)[i]	Dry wt (g)	First color (d)	Visible bud (d)	Anthesis (d)
Jubilee Red										
Pinched	34.6 a[ii]	52.9	46.8 a	6.2 b	0.0 b	302.8	46.4	65 b	65 c	96 c
800/1	35.2 a	51.9	46.3 ab	16.2 a	0.6 a	346.0	50.7	67 b	68 b	99 bc
1600/1	32.7 ab	50.6	44.6 ab	21.2 a	0.0 b	320.5	45.9	70 a	71 a	103 ab
800/2	31.0 b	49.6	43.4 b	19.2 a	0.0 b	306.3	44.3	70 a	71 a	104 a
Significance[iii]	*	NS	*	***	**	NS	NS	***	***	**
Neva Red										
Pinched	36.7	47.5	43.9	8.0 c	0.0	320.1	56.2 a	63 c	70 b	103 c
800/1	39.5	45.6	43.6	14.0 b	0.2	319.6	51.0 a	67 bc	73 b	111 b
1600/1	37.7	48.1	44.6	18.2 b	0.0	266.1	39.0 b	70 ab	80 a	124 a
800/2	35.4	46.2	42.6	18.8 a	0.0	267.9	39.0 b	71 a	79 a	123 a
Significance	NS	NS	NS	***	NS	NS	**	***	***	***
Noel Red										
Pinched	30.3 a	52.9 a	45.4 a	8.8 b	0.0	311.0 ab	44.3 ab	57 b	67 c	99 b
800/1	32.0 a	54.8 a	47.2 a	20.4 a	0.0	367.1 a	53.0 a	64 a	71 b	107 a
1600/1	27.4 b	47.5 b	40.8 b	21.6 a	0.0	279.8 bc	38.6 bc	67 a	75 ab	110 a
800/2	27.7 b	44.6 b	39.0 b	25.8 a	0.0	247.4 c	33.1 c	68 a	77 a	112 a
Significance	***	***	***	***	NS	***	***	***	***	***
Prestige Red										
Pinched	34.1	51.2	45.5	6.6 b	0.0	274.5 c	45.9 ab	70	69 b	99 b
800/1	34.9	52.4	46.6	16.2 a	0.2	369.5 a	55.8 a	70	72 ab	103 ab
1600/1	32.5	51.9	45.4	17.8 a	0.0	348.9 ab	52.5 ab	71	73 a	106 a
800/2	31.5	49.7	43.7	17.8 a	0.0	305.0 bc	44.0 b	71	75 a	108 a
Significance	NS	NS	NS	***	NS	***	*	NS	**	**
Prima Red										
Pinched	36.6	51.1	46.3	8.0 d	0.0	282.7	52.8	61 b	69 c	98 c
800/1	40.0	50.6	47.1	19.2 c	0.0	328.9	56.5	67 a	73 b	105 b
1600/1	39.6	47.7	45.0	24.0 b	0.0	299.3	51.7	68 a	79 a	110 a
800/2	36.7	47.8	44.1	31.4 a	0.0	290.9	47.2	69 a	79 a	112 a
Significance	NS	NS	NS	***	NS	NS	NS	***	***	***
Stargazer Red										
Pinched	31.5	44.4 ab	40.1 ab	10.0	0.0	253.8 ab	42.4 ab	64 b	71 b	108 b
800/1	34.1	47.6 a	43.1 a	12.3	0.3	295.0 a	51.1 a	66 ab	73 ab	111 ab
1600/1	28.5	41.1 b	36.9 b	12.5	0.0	175.3 b	27.9 b	68 a	77 a	115 ab
800/2	31.3	45.5 ab	40.8 ab	14.7	0.0	213.5 ab	34.0 ab	69 a	77 a	118 a
Significance	NS	*	*	NS	NS	*	*	*	*	*

[i] 1 ppm = 1 $mg \cdot L^{-1}$, 1 cm = 0.3937 inch, 1 g = 0.0353 oz.
[ii] Means within each cultivar in a column followed by the same letter are not significantly different.
[iii] Significance within columns are between treatments for each individual cultivar and dependent variable. NS, *, **, *** nonsignificant or significant at $P < 0.05$, 0.01, or 0.001, respectively.

Separate dikegulac sodium trials have shown that uniform spray volumes are needed for more consistent responses, and that treatment can be washed away if irrigated overhead within 24 h of the foliar spray (Barrett et al. 2013). Plants treated with dikegulac sodium in this study were similar in height to mechanically pinched controls in year 4. There was significantly greater height control in year 5 for cultivars Jubilee Red and Noel Red, thus highlighting the differences in cultivar response and, potentially, growing year. Some cultivars may still require the use of PGRs such as chlormequat chloride to enhance the visual appeal of lush vegetative growth or triazoles for height suppression (McDaniel et al. 1990).

Conclusions

When used properly, $BA+GA_{(4+7)}$ is a great tool for increasing plant height, especially when used to offset the overapplication of PGRs. $BA+GA_{(4+7)}$ can be applied early in the crop season to increase height; however, for most cultivars, there will be a tradeoff with a delay in flowering. Drench applications of BA+ $GA_{(4+7)}$ were less effective than foliar sprays, possibly because of the presence of bark in the substrate (Million et al. 1998) and delayed flowering in some cases.

The use of dikegulac sodium proved effective in promoting lateral branching on nonpinched poinsettia plants and, in some cultivars, produced a plant similar in appearance to mechanically pinched plants. One application of 1600 ppm was similar to two applications of 800 ppm. Growers should beware because when concentrations are too low, the apical shoot will remain dominant, and branching will be poor. However, foliar application sprays of PGRs 2 to 5 weeks after treatment with dikegulac sodium can alleviate this occurrence. The application time of dikegulac sodium was shown to be best at 1 week before the standard pinching of poinsettia. Caution should be taken with use of dikegulac sodium because it can significantly delay floral development, but this effect was variable and dependent on cultivar. Even though some cultivars were observed to be comparable in height to mechanically pinched plants when treated once at a concentration of 800 ppm, some delay was still prevalent in days to first color, visible bud, and/or anthesis.

It is imperative that growers consider the potential side effects of using these chemicals, which have been shown to vary by cultivar, and determine their specific cost-to-benefit ratio when evaluating the cultivars used in their production setting. As with any new production practice, it is recommended that producers should test treatments on a small number of plants before implementing them in large-scale production settings.

References cited

Alem P, Thomas PA, van Iersel MW. 2015. Controlled water deficit as an alternative to plant growth retardants for regulation of poinsettia stem elongation. HortScience. 50:565–569. https://doi.org/10.21273/HORTSCI.50.4.565.

Barrett JE, Bartuska CA, Weidman RF. 2013. Factors affecting the efficacy of dikegulac sodium on poinsettias (abstr). HortScience. 48:S145–S146. https://doi.org/10.21273/HORTSCI.48.9S.S1.

Berghage RD, Heins RD, Karlsson M, Erwin JE, Carlson W. 1989. Pinching technique influences lateral shoot development in poinsettia. J Am Soc Hortic Sci. 114:909–914. https://doi.org/10.21273/JASHS.114.6.909.

Berghage RD, Heins RD. 1991. Quantification of temperature effects on stem elongation in poinsettia. J Am Soc Hortic Sci. 116:14–18. https://doi.org/10.21273/JASHS.116.1.14.

Bergmann BA, Dole JM, Fisher P, Njue G, McCall I. 2017. Gibberellic acid promotes flower stem elongation in 'Renaissance Red' poinsettia. Can J Plant Sci. 97:14–16. https://doi.org/10.1139/cjps-2016-0111.

Blanchard MG, Runkle ES. 2008. Increasing stem elongation and bract size of poinsettia 'Freedom Red' with gibberellins and benzyladenine. Acta Hortic. 774:209–215. https://doi.org/10.17660/ActaHortic.2008.774.26.

Currey CJ, Lopez RG. 2011. Early flurprimidol applications suppress final height of four poinsettia cultivars. HortTechnology. 21:35–40. https://doi.org/10.21273/HORTTECH.21.1.35.

Dunn BL, Stanphill S, Goad C. 2021. Branching response of poinsettia 'Orange Spice' to a combination of pinching, no pinching, and atrimmec. HortScience. 56:1287–1288. https://doi.org/10.21273/HORTSCI16105-21.

Ecke P III, Faust JE, Higgins A, Williams J. 2004. The Ecke poinsettia manual. Ball Publ, Batavia, IL, USA.

Faust J, Heins R. 1996. Axillary bud development of poinsettia 'Eckespoint Lilo' and 'Eckespoint Red Sails' (*Euphorbia pulcherrima* Willd.) is inhibited by high temperatures. J Am Soc Hortic Sci. 121:920–926. https://doi.org/10.21273/JASHS.121.5.920.

Fisher PR, Heins RD, Lieth JH. 1996. Quantifying the relationship between phases of stem elongation and flower initiation in poinsettia. J Am Soc Hortic Sci. 121:686–693. https://doi.org/10.21273/JASHS.121.4.686.

Goreta S, Batelja K, Perica S. 2008. Growth of poinsettia as affected by cultivar, thinning, and pot size. HortTechnology. 18:122–129. https://doi.org/10.21273/HORTTECH.18.1.122.

Latimer JG, Whipker B. 2012. Selecting and using plant growth regulators on floricultural crops. Virginia Coop Ext Publ. 430-102. http://hdl.handle.net/10919/48109. [accessed 21 Jun 2022].

Liu BRD, Heins RD. 2002. Photothermal ratio affects plant quality in 'Freedom' poinsettia. J Am Soc Hortic Sci. 127:20–26. https://doi.org/10.21273/JASHS.127.1.20.

Mata DA, Botto JF. 2009. Manipulation of light environment to produce high-quality poinsettia plants. HortScience. 44:702–706. https://doi.org/10.21273/HORTSCI.44.3.702.

McDaniel GL, Graham ET, Maleug KR. 1990. Alteration of poinsettia stem anatomy by growth–retarding chemicals. HortScience. 25:433–435. https://doi.org/10.21273/HORTSCI.25.4.433.

Million JB, Barrett JE, Nell TA, Clark DG. 1998. Influence of pine bark on the efficacy of different growth retardants applied as a drench. HortScience. 33:1030–1031. https://doi.org/10.21273/HORTSCI.33.6.1030.

Padhye S, Runkle E, Olrich M, Reinbold L. 2008. Improving branching and postharvest quality. Greenhouse Product News 8: 36–42. https://www.canr.msu.edu/uploads/resources/pdfs/branchingandpostharvest.pdf. [accessed 20 Jun 2022].

Scoggins H, Mills H. 1998. Poinsettia growth, tissue nutrient concentration, and nutrient up-take as influenced by nitrogen form and stage of growth. J Plant Nutr. 21:191–198. https://doi.org/10.1080/01904169809365393.

Trejo L, Feria Arroyo TP, Olsen KM, Eguiarte LE, Arroyo B, Gruhn JA, Olson ME. 2012. Poinsettia's wild ancestor in the Mexican dry tropics: Historical, genetic, and environmental evidence. Am J Bot. 99:1146–1157. https://doi.org/10.3732/ajb.1200072.

US Department of Agriculture, National Agricultural Statistics Service. 2021. Floriculture crops 2020 summary. https://downloads.usda.library.cornell.edu/usda-esmis/files/0p0966899/s4656b62g/g445d913v/floran21.pdf. [accessed 21 Apr 2022].