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Growth Regulation of *Canna* x *generalis* 'Florence Vaughan'[1]

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Abstract

A study conducted in 1998 and 1999 determined the effects of B-Nine (daminozide) at rates of 2500 to 7500 ppm, Pistill (ethephon) at rates of 125 to 1000 ppm, Bonzi (paclobutrazol) at rates of 33 to 99 ppm, and Cutless (flurprimidol) at rates of 50 to 150 ppm on vegetative growth and flowering of *Canna* x *generalis* 'Florence Vaughan' during nursery container production and landscape establishment. Vegetative height 30 and 60 days after treatment (DAT), vegetative and inflorescence heights at first flower, and vegetative height at 30 days after planting (DAP) in the landscape were reduced by Cutless in 1998 and 1999. Vegetative height was suppressed quadratically by increasing rates of Cutless, an average of 46% and 42% (1998) and 19.5% and 30% (1999) at 30 and 60 DAT, respectively. In 1998, Cutless delayed flowering one to six days, while in 1999 flowering was accelerated one to eleven days compared to untreated plants. At 30 DAP, height suppression from the lowest rate of Cutless was 5% in 1998 and 14% in 1999; however the effect was not significant at 60 DAP. With increasing rates of Bonzi, vegetative heights at 30 DAT and at first flower were suppressed 16% to 29% and 12% to 25% in 1998, respectively, but not at all in 1999. In 1998, inflorescence height at first flower decreased linearly to a maximum of 20% as Bonzi rate increased, with no effect in 1999. B-Nine did not affect vegetative or inflorescence height or flowering in 1998 or 1999, except for a three- to eight-day delay in flowering in 1998 and an one- to six-day acceleration in flowering in 1999. The only observed treatment effect of Pistill was a 9% to 17% linear height reduction at 30 DAT in 1999. B-Nine and Pistill did not exhibit effective, consistent height suppression in the 1998 or 1999 experiment and do not appear useful in controlling canna lily height.

Index words: growth retardant, plant growth regulator, canna lily, herbaceous perennial.

Growth regulators used in this study: Bonzi (paclobutrazol), (±)-(R*, R*)-β-((4-chlorophenyl)methyl)-α-(1,1,-dimethylethyl)-1*H*-1,2,4,-triazole-1-ethanol; B-Nine (daminozide), [butanedioic acid mono (2,2-dimethylhydrazide)]; Cutless (flurprimidol), α-(1-methylethyl)-α-[4-(trifluromethoxy)phenyl]-5-pyrimidinemethanol; Pistill (ethephon), [(2-chloroethyl)phosphonic acid]*.

Species used in this study: 'Florence Vaughan' canna lily (*Canna* x *generalis* L. H. Bailey 'Florence Vaughan').

Significance to the Nursery Industry

Canna lily is often difficult to manage during production due to its rapid growth and top-heavy habit. Controlling canna lily height may reduce maintenance during production and retail stages and lower shipping costs to market. Application of Cutless at 50 to 150 ppm consistently provided significant height control of canna lily during container production, with minimal effect on time to flowering. However, inflorescence height was suppressed at first flower at all rates tested which likely reduced marketability. Following transplanting to the landscape, plants treated with the lowest rate of Cutless were only 5% (1998) and 14% (1999) shorter than untreated plants at 30 DAP, and Cutless treatment effects on vegetative height dissipated by 60 DAP. Inflorescence heights among treated and untreated plants appeared similar at 30 DAP. Due to excessive suppression of inflorescence height at first flower and residual vegetative height suppression persisting into the landscape, rates of Cutless tested may be considered excessive for canna lily. B-Nine, Pistill, and Bonzi at the rates tested were inconsistent or ineffective in controlling vegetative height of canna lily during nursery production.

Introduction

Canna x *generalis* 'Florence Vaughan' or canna lily is a herbaceous perennial, growing up to 110 cm (45 in) tall each growing season and producing gladiolus-like flowers from mid-summer through late fall. Flowers are sulphur yellow, with a large nasturtium orange blotch fading into spots. Flowers are held on scapes which typically extend around 10 cm (4 in) above the foliage when in bloom. The leaves are bright, apple green, elliptical, and originate sheath-like from the petiole (13). Canna lilies exhibit rapid growth and a top-heavy growth habit resulting from the upright position of the leaves. Canna lilies are often difficult to manage when grown in 3.8 liter (#1) containers due to these characteristics. Common problems include frequent blow-over during production and later at retail facilities, and increased shipping costs, especially when plants are racked during shipment.

Plant growth retardants (PGRs), including B-Nine, Pistill, Bonzi, and Cutless, are effective in suppressing height in numerous plant species (1, 4, 12, 15) and may offer benefits in the production, shipping, and marketing of canna lilies. B-Nine, Bonzi, and Pistill are labeled for use on herbaceous crops in greenhouse and nursery environments, while Cutless is labeled for use on turfgrass only. While these PGRs have been effective on numerous horticultural crops, none are specifically labeled for use on canna lily during nursery production. PGRs used in production occasionally have residual effects which carry over into the landscape (8, 9, 11). Suppressed growth in the landscape may reduce the intended visual effect of plants, as well as customer satisfaction. The objective of this study was to determine the effects of several rates of four PGRs on the height and flowering of canna lily during container production and landscape establishment.

Materials and Methods

The experiment was conducted twice, in spring 1998 and 1999. On April 3, 1998, and April 1, 1999, dormant canna lilies (*Canna* x *generalis* 'Florence Vaughan') in 3.8 liter

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(#1) containers were divided into quarters and repotted into 3.8 liter (#1) containers. The substrate was pine bark:sand (7:1, by vol) amended per m^3 (yd^3) with 10.7 kg (18 lb) 20N–3.3P–6K (Polyon 22–4–14, Pursell Industries, Sylacauga, AL), 0.9 kg (1½ lb) Micromax (The Scotts Company, Marysville, OH), and 3.0 kg (5 lb) dolomitic limestone. Plants were grown outdoors in full sun under twice daily overhead irrigation.

Prior to treatment application, plants were blocked by height and initial height measurements taken. Average initial heights of blocks ranged from 39.6 cm (15.6 in) to 43.3 cm (17.0 in) and 46.7 cm (18.4 in) to 54.1 cm (21.2 in) in 1998 and 1999, respectively. On May 6, 1998 and 1999, growth retardants were applied as foliar sprays in a volume of 0.2 liter/m^2 (2 qts/100 ft^2) using a CO_2 sprayer with a flat spray nozzle at 1.4 kg/cm^2 (20 psi) in a polyethylene greenhouse. Temperatures and relative humidities ranged from 30C (86F) to 39C (102F) and 41% to 58% (1998) and 19C (65F) to 19.5C (66F) and 95% (1999) during treatment application. PGRs applied were B-Nine at 2500, 5000, and 7500 parts per million (ppm); Bonzi at 33, 66, and 99 ppm; Cutless at 50, 100, and 150 ppm; and Pistill at 125, 250, 500, 750 and 1000 ppm, and an untreated control. The rates tested have been documented as effective on various crops (9, 10, 11). Treated plants were returned to the nursery container area on the following day.

The experimental design was a randomized complete block, with 10 single plant replications in 1998 and eight single plant replications in 1999. Plant height, from the substrate surface to the tallest vegetative point (uppermost leaf), was measured at 30 and 60 days after treatment (DAT) and at first flower. Plants were observed daily for flowering, and days to flower (DTF) were recorded daily and inflorescence height measured at first flower. DTF was defined as the number of days from PGR application until the first fully opened bloom. Inflorescence height was measured from the substrate surface to the top of the inflorescence of the first fully opened flower.

Following data collection at 60 DAT, selected treatments were transplanted into the landscape to assess residual PGR effects. Treatments selected for transplanting exhibited PGR treatment effects at 30 or 60 DAT. Height measurements were collected at 30, 60, and 90 days after planting (DAP) in the landscape. Plants transplanted into the landscape included five replications each from the control treatment and Bonzi and Cutless treatments in 1998 and eight replications each from the control and Cutless treatments in 1999. The experimental design for 1998 and 1999 was randomized block design. Landscape beds contained an organic soil amended with non-composted pine bark (screen size <12.5 mm (0.5 in)) to a depth of 5 to 7.5 cm (2 to 3 in) and mulched with 2.5 cm (1 in) of pine bark. Landscape beds were located in full sun and

Table 1. Vegetative and inflorescence heights and days to flower for *Canna* x *generalis* 'Florence Vaughan' treated with B-Nine, Pistill, Bonzi, or Cutless, 1998.

Growth retardant	Rate (ppm)	First flower			Vegetative height (cm)				
					Container production		Landscape		
		Days to flower	Vegetative height (cm)	Inflorescence height (cm)	30 DAT[z]	60 DAT	30 DAP[y]	60 DAP	90 DAP
Control	0	42	86.0	93.2	85.7	86.5	94.6	103.2	110.4
B-Nine	2500	40	87.0	99.8	86.4	97.0	—[x]	—	—
	5000	45	93.3	92.2	88.1	98.2	—	—	—
	7500	50	89.3	98.2	89.3	95.6	—	—	—
Significance[w]		L**	NS	NS	NS	NS	—	—	—
Pistill	125	42	86.5	85.6	81.6	92.5	—	—	—
	250	42	85.8	91.5	83.2	91.4	—	—	—
	500	45	89.5	86.1	89.4	93.7	—	—	—
	750	42	84.8	86.7	83.5	95.9	—	—	—
	1000	42	83.1	87.4	82.9	93.6	—	—	—
Significance		NS	NS	NS	NS	NS			
Bonzi	33	43	76.5	94.1	72.8	92.5	99.4	103.8	113.2
	66	46	78.2	92.3	68.2	90.5	93.8	111.6	117.0
	99	43	64.6	74.8	61.5	83.4	98.0	110.0	124.2
Significance		NS	L**	L*	L***	NS	NS	NS	L*
Cutless	50	41	52.9	47.3	50.2	55.1	90.2	108.6	109.8
	100	43	49.1	43.7	45.9	49.0	78.4	103.6	108.2
	150	48	43.9	30.4	43.6	46.1	81.2	98.8	108.8
Significance		L*	L*** Q***	L*** Q**	L*** Q***	L*** Q***	L*	NS	NS

[z]Days after treatment.

[y]Days after planting in the landscape.

[x]Treatment not included in experiment at indicated data collection.

[w]Nonsignificant (NS), linear (L), or quadratic (Q) response at the 5% (*), 1% (**), or 0.1% (***) level. Control included in regression analysis.

irrigated as needed. Data from both years were analyzed using orthogonal contrasts to test rate responses within a PGR; control plants were included in regression analyses.

Results and Discussion

B-Nine delayed flowering up to eight days in 1998, but advanced the time to first flower in 1999 compared to untreated plants (Tables 1 and 2). PGRs, including B-Nine at high rates (>8000 ppm foliar sprays), have been shown to delay flowering in ornamental crops (4, 11, 16). Gok and McDaniel (7) observed accelerated flowering using Sumagic, a triazole PGR similar to Bonzi. Although statistically significant, the observed delay of up to eight days in 1998 would probably not be a serious detriment to commercial growers. B-Nine had no effect on vegetative or inflorescence height in 1998 or 1999.

Pistill had no effect on canna lily height or flowering in 1998 (Table 1). The only significant treatment effect in 1999 was a linear reduction in vegetative height of up to 17% at 30 DAT as rate increased (Table 2). Pistill was previously shown to suppress the growth of Mexican sage (*Salvia leucantha)* for a limited duration under nursery conditions (2).

Bonzi had no effect on DTF in canna lily in either 1998 or 1999 (Tables 1 and 2). In 1998, increasing rates of Bonzi suppressed vegetative height linearly, 16% to 29% and 12% to 25% at 30 DAT and at first flower, respectively. In 1998, Bonzi treatments linearly suppressed inflorescence height at first flower up to 21% compared to untreated plants. Plants treated with Bonzi were transplanted into the landscape in 1998 but not in 1999. Treated and untreated transplanted plants were similar in heights at 30 and 60 DAP in 1998. At 90 DAP, vegetative height increased linearly (2% to 12%) with increasing rates of Bonzi, compared to untreated plants. This observed increase with PGR application has been previously reported and is thought to be associated with the accumulation of large carbohydrate reserves during growth suppression. These reserves are thought to trigger rapid growth once the retarding effect lessens (5, 10).

In contrast to 1998, Bonzi had no effect on height in 1999. Previous research has shown one factor influencing PGR efficacy is the stage of plant development at the time of PGR application (6). Paclobutrazol, the active ingredient in Bonzi, is absorbed through leaves, stems, and roots. However, only the material absorbed through the stems and roots is readily translocated to apical meristems via the xylem where gibberellin biosynthesis is inhibited (14). Earlier spray applications of Bonzi typically result in better contact with plant stems, since there is less coverage from leaf canopies (6). Vegetative heights at the time of PGR application in 1998 ranged from 39.6 to 43.4 cm (15.6 to 17.0 in) in contrast to

Table 2. Vegetative and inflorescence heights and days to flower for *Canna* x *generalis* 'Florence Vaughan' treated with B-Nine, Pistill, Bonzi, and Cutless, 1999.

Growth retardant	Rate (ppm)	First flower			Vegetative height (cm)				
					Container production		Landscape		
		Days to flower	Vegetative height (cm)	Inflorescence height (cm)	30 DAT[z]	60 DAT	30 DAP[y]	60 DAP	90 DAP
Control	0	47	82.1	105.2	68.0	91.0	104.2	111.1	114.8
B-Nine	2500	46	87.0	113.5	71.6	96.7	—[x]	—	—
	5000	41	83.2	99.7	72.1	95.1	—	—	—
	7500	45	87.7	110.5	73.1	92.2	—	—	—
Significance[w]		L**	NS	NS	NS	NS	—	—	—
Pistill	125	42	69.8	89.3	63.7	85.3	—	—	—
	250	40	73.8	91.5	65.8	86.8	—	—	—
	500	45	73.2	92.5	62.2	89.7	—	—	—
	750	52	83.1	101.5	60.3	91.5	—	—	—
	1000	48	71.0	85.8	57.0	82.6	—	—	—
Significance		NS	NS	NS	L**	NS	—	—	—
Bonzi	33	45	79.7	106.3	68.1	89.2	—	—	—
	66	43	73.8	94.1	62.7	83.8	—	—	—
	99	47	77.2	101.7	66.0	88.0	—	—	—
Significance		NS	NS	NS	NS	NS	—	—	—
Cutless	50	42	58.1	53.5	56.7	63.8	90.8	111.5	114.8
	100	46	54.5	32.6	54.8	56.6	83.2	100.3	108.2
	150	36	60.2	27.4	54.5	58.8	81.3	105.8	110.0
Significance		L*	L*** Q***	L*** Q***	L*** Q*	L*** Q***	L***	NS	NS

[z]Days after treatment.

[y]Days after planting in the landscape.

[x]Treatment was not included in experiment at time of indicated data collection.

[w]Nonsignificant (NS), linear (L), or quadratic (Q) response at the 5% (*), 1% (**), or 0.1% (***) level. Control included in regression analysis.

heights of 46.7 to 54.1 cm (18.4 to 21.2 in) in 1999. The lack of height suppression from Bonzi treatments in the 1999 study is possibly linked to PGR application to larger, more developed plants.

Effects on DTF from Cutless treatments varied in the two experiments. In 1998, a linear increase in DTF of up to six days was observed with increasing rates of Cutless (Table 1). However, Cutless accelerated flowering one to eleven days in the 1999 study (Table 2). Although statistically significant, the observed effects on time to flower are not likely to be a major detriment or benefit to commercial growers, especially if the effects are unpredictable.

Of the four PGRs studied, only Cutless consistently suppressed vegetative and inflorescence heights during container production in both 1998 and 1999. These results agree with those of Criley and Lekawatana (3), who reported Cutless was more effective than A-Rest (ancymidol) or Bonzi in controlling plant height of false bird of paradise (*Heliconia stricta)*.

At first flower, increasing rates of Cutless suppressed inflorescence height quadratically 50% to 68% in 1998 and 50% to 75% in 1999. Vegetative height at first flower was quadratically suppressed by increasing rates of Cutless 39% to 50% in 1998 and 30% to 35% in 1999. Average inflorescence height of Cutless-treated plants was less than that of the foliage. This suppression was least pronounced at the lowest rate applied (50 ppm) with foliage on average 5 cm (2 in) taller than inflorescences in both experiments. Suppression of inflorescence heights compared to foliage heights at the higher Cutless rates was similar (6 cm (2.4 in) to 7 cm (2.8 in)) in 1998, but significantly more pronounced in 1999 with differences of 22 cm (8.7 in) to 33 cm (13.0 in). In previous research (10), Cutless decreased inflorescence length and width of butterfly bush (*Buddleia davidii)*. For canna lilies, the inflorescence height reduction detracted from the floral display of treated plants which would be detrimental to plant marketability. Following transplanting, inflorescence heights among treated and untreated plants appeared similar by 30 DAP.

At 30 DAT, increasing rates of Cutless suppressed vegetative height 42% to 50% in 1998 and 18% to 21% in 1999. At 30 DAT, the lowest rate of Cutless suppressed canna lily height more than the highest rate of Bonzi in either years.

At 60 DAT, vegetative height of Cutless-treated plants was quadratically suppressed 37% to 47% and 21% to 39% with increasing rates compared to untreated plants in 1998 and 1999, respectively. In 1998, the percent decrease in height lessened between 30 and 60 DAT indicating a dissipation of growth suppression. However, height in 1999 was suppressed to a greater extent at 60 DAT than at 30 DAT.

Cutless-treated and untreated plants were transplanted into the landscape both years to assess residual effects of PGRs in the landscape. At 30 DAP, height was suppressed linearly with increasing Cutless rates, 5% to 14% in 1998 and 14% to 23% in 1999. The difference in height between plants treated at the lowest rate of Cutless and untreated plants was small, only 5% (1998) and 14% (1999); this difference would hardly be distinguishable to the consumer. Cutless treatment effects on vegetative height dissipated between 30 and 60 DAP.

In summary, B-Nine and Pistill did not exhibit effective, consistent height suppression in the 1998 or 1999 experiment. Based on these results neither PGR at the rates tested appears useful in controlling canna lily height. Bonzi provided growth suppression for a limited time in 1998, but not at all in 1999.

Cutless was effective and consistent in controlling height of canna lily. However, based on the excessive retardation of inflorescence height with all rates tested and residual height suppression in the landscape observed with 100 and 150 ppm, plant marketability may be reduced at initial flowering, even at the lowest rate tested. Vegetative height suppression with increasing Cutless rates was primarily quadratic with the most dramatic height difference between untreated plants and those treated with the lowest rate. Relatively little vegetative height difference occurred between the lowest and highest rates, suggesting little justification for exceeding an application rate of 50 ppm. The reduction in plant size at the lowest rate tested should facilitate shipping and handling and reduce maintenance activities during production. Height of canna lily treated with the lowest Cutless rate was only 5% (1998) and 14% (1999) less than that of untreated plants at 30 DAP, which should not detract from the plant's landscape appeal to consumers. Additionally, following transplanting inflorescence heights among treated and untreated plants appeared similar by 30 DAP.

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