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Growth Regulators and Pruning Alter Growth and Axillary Shoot Development of *Dianthus*[1]

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Abstract

Annual carnation, *Dianthus caryophyllus* L., and garden pink, *Dianthus chinensis* L., were treated with foliar sprays of Bonzi (paclobutrazol), Cycocel (chlormequat chloride), or Pro-Shear (BA), and/or pruned to suppress shoot elongation or promote axillary shoot development. Bonzi (paclobutrazol) at 100 or 200 ppm was effective in suppressing shoot elongation of annual carnation over a 14-week period and garden pink over an 8-week period without increasing days to flower of either species. The combination of pruning and Bonzi (paclobutrazol) inhibited shoot elongation of both species compared to pruning alone. Flowering of both species was delayed 11 to 14 days compared to the control when pruning was combined with Bonzi (paclobutrazol). Cycocel (chlormequat chloride) suppressed shoot elongation of annual carnation but was not as effective as Bonzi (paclobutrazol); shoot elongation of garden pink was only suppressed for 2 weeks after Cycocel (chlormequat chloride) application. Application of Pro-Shear (BA) at 100 or 200 ppm did not promote axillary shoot development of either species nor did Pro-Shear (BA) combined with pruning. Pruning of annual carnation and garden pink suppressed shoot elongation through week 7 and week 4, respectively, compared to the control. Pruning of annual carnation increased axillary shoot development compared to all other treatments, while pruning of garden pink decreased flower and primary axillary shoot numbers. Pruning delayed flowering in both species about 12 days compared to the control.

Index words: paclobutrazol, chlormequat chloride, BA, Bonzi, Cycocel, Pro-Shear, growth retardant, pruning

Growth regulators used in this study: Bonzi (paclobutrazol), β-[(4-chlorophenyl)methyl]-α-(1,1-dimethylethyl) -1*H*-1,2,4,-triazole-1-ethanol; Cycocel (chlormequat chloride), 2-chloro-*N*,*N*,*N*-trimethylethanaminium chloride; Pro-Shear (BA), *N*-(phenylmethyl)-1*H*-purin-6-amine.

Species used in this study: annual carnation (*Dianthus caryophyllus* L. 'Knight Hybrid Scarlet'); garden pink (*Dianthus chinensis* L. 'Queen of Hearts').

Significance to the Nursery Industry

In a competitive industry where increased efficiency is essential to survival, a reduction in labor requirements reduces production costs and adds to profits. Bonzi (paclobutrazol), a growth retardant, is effective on a wide range of plants including *Dianthus*. Stem elongation of treated plants may be inhibited over the entire production cycle as a result of a single application of Bonzi (paclobutrazol). Cycocel (chlormequat chloride), a commonly used growth retardant on *Dianthus* species, usually requires 2-3 applications to suppress stem elongation, depending on the cul-

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tivar. By decreasing the number of growth regulator applications necessary to inhibit stem elongation, less time and money is invested in production of a crop. In this study, a single application of Bonzi (paclobutrazol) at 100 ppm suppressed shoot elongation of 2 *Dianthus* species, thereby reducing labor costs for growers who normally use Cycocel (chlormequat chloride).

Introduction

When used as bedding plants or pot crops, carnation (*Dianthus caryophyllus*) and garden pink (*Dianthus chinensis*) are treated as annuals, blooming the first year from seed. Annual carnations produce large double blooms on 45 cm (18 in) stems and are traditionally used as cut flowers. Garden pink blooms in loose clusters of single flowers on 40 cm (16 in) stems and are more commonly used as bedding plants. Both species provide a showy display of blooms in shades of red, pink or white. When these plants are marketed as pot crops, they should be proportional in size for 10.2 cm (4 in) pots which may require the use of growth retardants (1). This production target may require growth retardants or pruning to control plant size. Bonzi (paclobutrazol) has suppressed stem elongation of many plant species including chrysanthemum (9), geranium (2, 12) and a wide variety of other floricultural crops (6). Cycocel (chlormequat chloride) effectively inhibited shoot elongation of *Dianthus chinensis* 'Snowfire' and *Dianthus barbatus* 'Indian Carpet' cultivars (10), Reiger begonia (5) and ivy geranium (4).

Synthetic cytokinins, such as Accel (PBA, Shell Oil Co.), have increased the number of vegetative shoots or suppressed shoot elongation of some *Dianthus* species and cultivars (10, 13) when used at rates ranging from 200 to 1000 ppm; however, chlorosis was observed on foliage of some cultivars (10). By increasing the number of axillary shoots on *Dianthus* species, a greater number of blooms may be produced (12).

The objectives of this experiment were to suppress shoot elongation of annual carnation and garden pink with Bonzi (paclobutrazol) or Cycocel (chlormequat chloride), and to increase the number of axillary shoots with pruning or the synthetic cytokinin Pro-Shear (BA), making these species potentially more proportional and attractive when offered as 10.2 cm (4 in) pot crops. Pro-Shear (BA) was selected for testing in this study for its effectiveness on axillary shoot development without injury to foliage of apple (11), *Peperomia* (3), and *Cordyline* (7) at rates ranging from 100 to 500 ppm; the lower rates from these studies were selected to avoid possible foliar injury to the *Dianthus* species in this experiment. Pruning is an effective method of controlling plant size and increasing branching of numerous horticultural crops, including *Capsicum* (8).

Materials and Methods

Seeds of 'Knight Hybrid Scarlet' annual carnation and 'Queen of Hearts' garden pink were sown on December 11, 1987, in 36 cell flats of Pro-Mix BX (Premier Brands, Inc., New Rochelle, NY) and placed in a double polyethylene greenhouse under intermittent mist (10 sec/5 min) until cotyledons had fully emerged. Minimum day/night temperatures in the greenhouse were 21°/16°C (70°/60°F). Seedlings were transplanted to standard 10.2 cm (4 in) pots on January 29, 1988. Foliar applications of growth regulating chemicals were made seventeen days after transplanting to a point just prior to runoff. Plants of annual carnation and garden pink were about 8 cm (3 in) and 12 cm (5 in) tall, respectively at the time of application.

Treatments consisted of Bonzi (paclobutrazol) at 100 or 200 ppm, Pro-Shear (BA) at 100 or 200 ppm, 2 applications of Cycocel (chlormequat chloride) at 3500 ppm applied 3 weeks apart, and an untreated control. The surfactant Buffer-X (0.2%) was added to spray solutions. There were also 3 treatments which included pruning of plants above the fourth node to a height of about 4 cm (1.6 in) just prior to chemical application. These treatments consisted of pruning alone or combined with an application of Bonzi (paclobutrazol) or Pro-Shear (BA) at 100 ppm on annual carnation or 200 ppm on garden pink. Garden pink received a higher rate of Bonzi (paclobutrazol) or Pro-Shear (BA) than annual carnation due a faster growth rate and greater mature height of the selected cultivar.

Plants were fertilized weekly with 200 ppm N from 20N-4.3P-16.6K (20-10-20) Peter's Peatlite Special (Grace-Sierra, Fogelsville, PA). Heights from the surface of the growth medium to the vegetative shoot apex of annual carnation was determined 2, 4, 7, 10, and 14 weeks after treating; heights of garden pink were measured 2, 4 and 8 weeks after treating. Days to first fully open flower from date of seeding was determined as plants flowered. Final data were collected when the last plant flowered; this data consisted of numbers of axillary shoots longer than 1 cm (0.4 in), numbers of open flowers and flower buds and shoot dry weight. Treatments were completely randomized with seven single-plant replicates of annual carnation and eight single-plant replicates of garden pink.

Results and Discussion

Beginning at week 4 and continuing through the termination of the study at week 14, the heights of annual carnation treated with Bonzi (paclobutrazol) were shorter as rate increased (Table 1). Fewer axillary shoots developed on Bonzi (paclobutrazol) treated plants than on control plants (Table 2). Shoot dry weight decreased with increasing concentrations of Bonzi (paclobutrazol). Heights of plants treated with Cycocel (chlormequat chloride) were suppressed beginning at week 4 and throughout the experimental period. However, treatment with Bonzi (paclobutrazol) was more effective in suppressing growth during the same time period. Neither days to flower, flower number nor flower bud number was affected by Bonzi (paclobutrazol) or Cycocel (chlormequat chloride) application. Plants treated with Pro-Shear (BA) at 100 or 200 ppm did not differ from the control in any of the observations measured.

The pruned treatment grew to a height equal to that of the control by week 10 and produced a greater number of axillary shoots; however, flowering was delayed about 11 days. Neither shoot dry weight nor numbers of flowers or flower buds of pruned plants differed from the control. When pruning was combined with 100 ppm Bonzi (paclobutrazol), plant height was suppressed compared to the pruned treatment beginning at week 4 and continuing until experiment termination at week 14. Numbers of axillary shoots and shoot dry weight decreased when pruning was combined with Bonzi (paclobutrazol) compared to the pruned treatment; flower number was decreased while bud number and days to flower did not differ from the pruned treatment. The

Table 1. Plant heights of *Dianthus caryophyllus* 'Knight Hybrid Scarlet' in response to three plant growth regulators, pruning or combinations.

Treatment	Rate (ppm)	Plant heights (cm) Weeks after treatment applied 2	4	7	10	14
Bonzi (paclobutrazol)	100	7.3	10.2	13.9	16.3	17.0
	200	6.3L[z]	8.8L	11.6Q	14.0Q	14.4Q
	100 + pr[y]	5.4	7.8	12.9	17.6	18.7
Pro-Shear (BA)	100	8.2	13.4	25.5	30.6	31.3
	200	7.8ns	13.2ns	25.9ns	31.3ns	31.1ns
	100 + pr	5.5	9.7	19.5	29.0	31.0
Cycocel (chlormequat chloride)	3500	8.1	10.6	17.3	21.9	24.7
Pruned	—	6.6	10.8	20.3	30.3	33.1
Control	—	8.7	14.3	26.1	31.1	31.6
LSD[x]		1.4	1.9	2.4	3.6	3.7

[z]Significance of regression analysis at P = 0.05: L = linear; Q = quadratic; ns = nonsignificant; control, but not plant growth regulator + pruning treatment, included in regression analysis.

[y]pr = pruned in addition to spray application.

[x]Mean separation within columns by a Fisher's least significant test, P = 0.05; LSD used for comparisons among growth regulators.

combination of pruning and Pro-Shear (BA) at 100 ppm produced plants with fewer axillary shoots than the pruned treatment; no other observations were significantly different.

As rate of Bonzi (paclobutrazol) increased, plant height of garden pink was suppressed beginning 2 weeks after spray application and continuing until experiment termination at week 8 (Table 3). Numbers of secondary and tertiary axillary shoots and shoot dry weight were suppressed with Bonzi (paclobutrazol) application; numbers of primary axillary shoots were suppressed at the 200 ppm rate (Tables 4 and 5). Total number of flowers and days to flower did not differ from the control when plants were treated with Bonzi (paclobutrazol).

When pruning was combined with Bonzi (paclobutrazol) at 200 ppm, plant height was suppressed compared to the pruned treatment beginning at week 4. However, plant height did not differ from the unpruned 200 ppm Bonzi (paclobutrazol) treatment during the experimental period. When plants were pruned and treated with 200 ppm Bonzi (paclobutrazol), fewer secondary and tertiary axillary shoots developed, while numbers of primary axillary shoots did differ when compared to pruned plants. Flower number and

Table 2. Axillary shoot, flower, and flower bud number, shoot dry weight and days to flower of *Dianthus caryophyllus* 'Knight Hybrid Scarlet' in response to three plant growth regulators, pruning or combinations, 14 weeks after treatment.

Treatment	Rate (ppm)	Axillary shoot no.	Flower no.	Flower bud no.	Shoot dry weight (g)	Days to flower[z]
Bonzi (paclobutrazol)	100	13.0	9.7	13.7	9.0	143
	200	14.0Q[y]	9.3ns	16.9ns	7.9Q	145ns
	100 + pr[x]	18.0	5.3	19.4	8.8	156
Pro-Shear (BA)	100	16.6	11.7	13.0	14.4	145
	200	16.1ns	14.1ns	11.1ns	13.2ns	143ns
	100 + pr	16.2	9.7	17.5	13.6	149
Cycocel (chlormequat chloride)	3500	13.1	13.1	12.0	10.5	140
Pruned	—	23.1	12.4	15.1	14.2	153
Control	—	16.3	13.4	11.4	14.0	142
LSD[w]		2.2	4.3	5.6	1.6	6.4

[z]Days to flower = number of days from date of seeding to opening of first flower.

[y]Significance of regression analysis at P = 0.05: Q = quadratic; ns = nonsignificant; control, but not plant growth regulator + pruning treatment, included in regression analysis.

[x]pr = pruned in addition to spray application.

[w]Mean seperation within columns by a Fisher's least significant test, P = 0.05; LSD used for comparisons among growth regulators.

Table 3. Plant heights of *Dianthus chinensis* 'Queen of Hearts' in response to three plant growth regulators, pruning or combinations.

Treatment	Rate (ppm)	Applic. no.	Plant heights (cm) Weeks after treatment applied 2	4	8
Bonzi (paclobutrazol)	100	1	6.7	10.6	19.0
	200	1	6.2Q[z]	7.7Q	13.0Q
	200 + pr[y]	1	4.6	7.7	12.8
Pro-Shear (BA)	100	1	8.9	23.8	33.0
	200	1	11.5Q	28.2Q	34.4ns
	200 + pr	1	5.5	13.8	36.5
Cycocel (chlormequat chloride)	3500	2	9.1	23.7	32.0
Pruned	—	—	6.3	14.3	31.5
Control	—	—	12.3	26.2	34.6
LSD[x]			1.8	3.3	3.4

[z]Significance of regression analysis at P = 0.05; Q = quadratic; ns = nonsignificant; control, but not plant growth regulator + pruning treatment, included in regression analysis.

[y]pr = pruned in addition to spray application.

[x]Mean separation within columns by a Fisher's least significant test, P = 0.05; LSD used for comparisons among growth regulators.

shoot dry weight of plants pruned and treated with Bonzi (paclobutrazol) were less than the pruned treatment, while days to flower did not differ.

Plants receiving an application of Pro-Shear (BA) at 100 or 200 ppm did not differ in height from the control. When Pro-Shear (BA) was applied at 100 ppm, fewer secondary and tertiary axillary shoots developed compared to the control while the number of primary axillary shoots did not differ. Numbers of primary, secondary and tertiary axillary shoots did differ from the control when plants were treated with Pro-Shear (BA) at 200 ppm. Days to flower and flower number of plants treated with Pro-Shear (BA) did not differ from the control, but shoot dry weight decreased with increasing rate. Heights of plants that were pruned and received an application of Pro-Shear (BA) at 200 ppm were suppressed through week 4. Shoot dry weight and primary and tertiary axillary shoot numbers were less than the control, while secondary axillary shoots did not differ when pruning was combined with Pro-Shear (BA) at 200 ppm; days to flower was delayed about 13 days.

Plants treated with Cycocel (chlormequat chloride) did not differ in height from the control 4 weeks after initial application. Shoot dry weight and number of tertiary axillary shoots were less with the application of Cycocel (chlormequat chloride) when compared to the control; no other observations were significantly different. When plants were

Table 4. Primary, secondary and tertiary axillary shoot numbers of *Dianthus chinensis* 'Queen of Hearts' in response to three plant growth regulators, pruning or combinations.

Treatment	Rate (ppm)	Applic. no.	Primary axillary shoot no.	Secondary axillary shoot no.	Tertiary axillary shoot no.
Bonzi (paclobutrazol)	100	1	8.7	24.1	8.2
	200	1	5.9L[z]	26.6Q	4.5L
	200 + pr[y]	1	6.0	23.1	0.6
Pro-Shear (BA)	100	1	11.1	26.7	9.7
	200	1	9.0Q	32.7ns	17.7Q
	200 + pr	1	8.2	36.6	12.1
Cycocel (chlormequat chloride)	3500	2	9.6	33.0	14.0
Pruned	—	—	6.9	31.2	14.6
Control	—	—	10.2	33.1	19.7
LSD[x]			1.7	5.4	4.7

[z]Significance of regression analysis at P = 0.05; L = linear; Q = quadratic; ns = nonsignificant; control, but not plant growth regulator + pruning treatment, included in regression analysis.

[y]pr = pruned in addition to spray application.

[x]Mean separation within columns by a Fisher's least significant test, P = 0.05; LSD used for comparisons among growth regulators.

Table 5. Flower number, days to flower and shoot dry weight of *Dianthus caryophyllus* 'Queen of Hearts' in response to three plant growth regulators, pruning or combinations.

Treatment	Rate (ppm)	Applic. no.	Flower no.	Days to flower[z]	Shoot dry weight (g)
Bonzi (paclobutrazol)	100	1	46.2	97	5.6
	200	1	44.7L[y]	98ns	4.9Q
	200 + pr[x]	1	12.6	110	3.7
Pro-Shear (BA)	100	1	53.0	100	8.6
	200	1	47.7ns	97ns	8.4L
	200 + pr	1	32.1	109	6.9
Cycocel (chlormequat chloride)	3500	2	45.5	99	7.9
Pruned	—	—	27.9	108	8.3
Control	—	—	52.5	96	10.4
LSD[w]			10.8	4.0	1.0

[z]Days to flower = number of days from date of seeding to opening of first flower.

[y]Significance of regression analysis at P = 0.05: L = linear; Q = quadratic; ns = nonsignificant; control, but not plant growth regulator + pruning treatment, included in regression analysis.

[x]pr = pruned in addition to spray application.

[w]Mean separation within columns by a Fisher's least significant test, P = 0.05; LSD used for comparisons among growth regulators.

pruned, heights were less than the control through week 4, while shoot dry weight, flower number, primary and tertiary axillary shoots were less compared to the control. Time to flower was delayed about 12 days as a result of pruning.

Growth regulator application did not induce any symptoms of phytotoxicity, such as chlorosis, on either species. Both species displayed darker green foliage as a result of Bonzi (paclobutrazol) application which may indicate improved plant quality when marketing plants. Effects of Bonzi (paclobutrazol) application persisted until experiment termination (8 weeks for garden pink and 14 weeks for annual carnation). Two applications of Cycocel (chlormequat chloride) inhibited shoot elongation of annual carnation, though not as effectively as Bonzi (paclobutrazol). Messinger and Holcomb (10) reported effective height control of selected *Dianthus* cultivars using single applications of Cycocel (chlormequat chloride) at 1500 to 6000 ppm; however, with increasing rate, degree of phytotoxicity also increased. Garden pink may require at least 3 applications of Cycocel (chlormequat chloride) at 2-week intervals to suppress shoot elongation without risk of severe phytotoxicity; 2 applications at 3500 ppm at 3-week intervals were ineffective. The rates of synthetic cytokinins necessary to suppress shoot elongation or increase axillary shoot development are dependent on the *Dianthus* cultivar being tested (10). Though Pro-Shear (BA) rates in this experiment were selected to avoid foliar injury, they did not effectively increase axillary shoot development. Higher rates of Pro-Shear (BA) or another synthetic cytokinin may be necessary for efficacy on the two *Dianthus* cultivars evaluated in this study.

(*Ed. note:* This paper reports the results of research only, and does not imply registration of a pesticide under amended FIFRA. Before using any of the products mentioned in this research paper, be certain of their registration by appropriate state and/or federal authorities.)

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