HortScience 29(4):285–288. 1994.

Flowering and Growth of *Phalaenopsis* Orchids following Growth Retardant Applications

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Additional index words. plant growth regulator, moth orchid

Abstract. **Bare-root, mature, hybrid *Phalaenopsis* seedlings were dipped in one of three growth retardant solutions for 5 seconds or sprayed with a growth retardant 4 weeks following planting during inflorescence elongation. Dipping the entire plant in daminozide (2500, 5000, or 7500 mg·liter^{-1}) before planting delayed flowering by 5-13 days, whereas foliar applications had no effect. Paclobutrazol (50, 100, 200, or 400 mg·liter^{-1}) or uniconazole (25, 50, 100, or 200 mg·liter^{-1}) dips did not affect the bloom date but effectively restricted inflorescence growth below the first flower (stalk). Increasing concentrations produced progressively less growth. Foliarly applied retardant treatments were less effective than dipping. Flower size, flower count, and stalk thickness were unaffected by treatments. Dipping in high concentrations of paclobutrazol (200 or 400 mg·liter^{-1}) or uniconazole (100 or 200 mg·liter^{-1}) caused plants to produce small, thick leaves. During the second bloom season, inflorescence emergence and bloom date were progressively delayed by increasing concentrations of paclobutrazol and uniconazole. Neither retardant affected flower count or size. Foliarly applied daminozide increased stalk length. In another experiment, foliar paclobutrazol treatment restricted stalk growth more effectively when sprayed before inflorescence emergence. Its effect progressively decreased when treatment was delayed. Paclobutrazol concentrations from 125 to 500 mg·liter^{-1} were equally effective in limiting stalk elongation when applied to the foliage. Chemical names used: butanedioic acid mono (2,2-dimethylhydrazide) (daminozide); (E)-1- *(p* -chlorophenyl)-4,4-dimethyl-2-(1,2,4-triazol-1-yl)-1-penten-3-ol(uniconazole); (2*RS,* 3 *RS)* -1-(4-chlorophenyl)-4,4-dimethyl-2-(1 *H*- 1,2,4-triazol-1-yl) pentan-3-ol (paclobutrazol).**

The demand for *Phalaenopsis* (moth orchid) as a potted flowering plant has increased rapidly in recent years (Thomas, 1992; Vasquez and Frier, 1991). In addition to domestic propagation, >250,000 plants were imported to the United States in 1992. This orchid has a relatively low light requirement (Poole and Seeley, 1977; Taiwan Sugar Corp., 1989) and a bloom period often surpassing 2–3 months. *Phalaenopsis* is easier to grow than many other orchids (Gordon, 1990; McDowell, 1992; Wang, 1992).

One goal of current breeding research is to introduce more compact selections of moth orchids for the commercial trade. Although dwarf cultivars with small flowers are available (Gavin and Griesbach, 1991; Griesbach, 1985), most *Phalaenopsis* cultivars with large flowers have long inflorescences, which results in high shipping costs for the taller boxes that must be used. An assessment of commercially available growth retardants for controlling inflorescence length would be helpful. Because *Phalaenopsis* is a perennial and often reblooms for the consumer, the long-term effect of growth retardants on future growth and flowering must be evaluated. Therefore, our experiments were conducted to determine the immediate and long-term impact of three growth retardants on *Phalaenopsis* flowering and growth. The effect of paclobutrazol, applied at various stages of inflorescence development, on flowering also was evaluated.

Received for publication 21 June 1993, Accepted for publication 5 Nov. 1993. Some plants used in this study were donated by Taiwan Sugar, Taipei, Taiwan, R.O.C. Uniconazole was donated by Valent U.S.A., Walnut Creek, Calif. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact,
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Materials and Methods

Effect of various growth retardants. Bare-root, mature seedlings of a white-flowered *Phalaenopsis* hybrid *[P. amabilis* (L.) Blume × *P.* Mount Kaala 'Elegance') with five to seven leaves spreading 30–35 cm were imported from Taiwan (Taiwan Sugar Corp., Taipei) by airfreight. Plants were in transit for 9 days and remained turgid with no visible inflorescences on arrival (13 Oct. 1991). Eleven groups of eight plants were immersed for 5 sec in an aqueous solution of daminozide at 2500, 5000, or 7500 mg·liter^{-1} (B-Nine SP; Uniroyal Chemical, Middlebury, Conn.); paclobutrazol at 50, 100, 200, or 400 mg·liter^{-1} (Bonzi, Sandoz, Chicago); or uniconazole at 25, 50, 100, or 200 mg·liter^{-1} (Sumagic; Valent U.S.A., Walnut Creek, Calif.) immediately following arrival. We dipped control plants in water. Then all plants were planted.

The medium consisted of equal volumes perlite (No. 3; Grace-Sierra, Fogelsville, Pa.) horticultural-grade charcoal, and Metro Mix 250 (Grace-Sierra, Milpitas, Calif.) amended with 250 g Micromax/m^3 (Grace-Sierra, Milpitas). Among the charcoal particles, 35% were >8 mm; 21% were 8–6.3 mm; 32% were 6.3–4 mm; and 14% were <4 mm.

A total of 48 additional plants were potted, and after 4 weeks when flower spikes had started to elongate, plants were given a foliar spray of water, daminozide (2500 or 5000 mg·liter^{-1}), paclobutrazol (250 or 500 mg·liter^{-1}), or uniconazole (100 or 200 mg·liter^{-1}). All solutions contained 0.05% Tween 20 (Fisher-Biotech, Fair Lawn, N.J.). The spray solution was used at an average rate of 12 ml/plant. The medium surface was not covered during spraying to simulate a commercial practice. The air was 27C at the time of treatment. Single-plant experimental units were replicated eight times. Treatments were arranged in a randomized complete-block design. We conducted regression analyses within each application method, using the concentration of each retardant as the independent variable.

Plants were placed on a greenhouse bench and received a maximum photosynthetic photon flux from 460 (Oct. 199 1) to 270 (Jan. 1992) µmol·m^{-2}·s^{-1} at noon. All pots were irrigated by hand with water containing 0.5 g 20N–8.6P–16.6K water-soluble fertilizer (Grace-Sierra) per liter.

We started to collect data when the fifth flower opened; our data included first flower width, number of flowers on the main inflorescence, total inflorescence length, and date that the first flower became fully open. We also recorded inflorescence length between the base and first flower (stalk), its diameter at the middle of the fourth internode, and internode length between the first and second flowers.

To determine retardant effects on long-term plant performance, plants were watered, fertilized, and maintained on the same bench. The average greenhouse air was 22.7 (day)/16.5C (night) in Jan. 1992 and 32.9 (day)/25.7C (night) in July 1992.

We started examining the plants daily on 1 Aug. 1992, recording date of inflorescence emergence from a leaf base and data similar to those collected during the previous season. Length and width of the uppermost fully matured leaf were determined. The experiment ended in Apr. 1993.

Effects of paclobutrazol at various stages. *Phalaenopsis* (Snow Swallow × Hisa Nasu) plants with 30- to 35-cm leaf span, propagated by tissue culture, were grown in 470 cm^3 New

Zealand sphagnum moss in soft, clear-plastic, 600-cm^3 pots (10.5 cm in diameter). Plants received 0.4 g·liter^{-1} of a 10N–12.9P–16.6K water-soluble fertilizer (Grace-Sierra, Milpitas) at each irrigation. Because inflorescence emergence was uniform, plants were selected and sprayed with paclobutrazol on three dates. On 5 Nov. 1992, a total of 20 plants without visible flower bud (pre-emergence) were selected. Half received a foliar application of paclobutrazol, and the other half were controls. An additional two groups of 10 plants, with flower buds just breaking the leaf base (bud stage) or flower buds 1 cm long, also were treated with paclobutrazol. On 18 Nov., 10 plants with 2.5-cm-long inflorescences and another 10 plants with 5-cm-long inflorescences were selected and treated. Two groups of 10 plants 7.5- or 10-cm-long inflorescences were selected and treated on 25 Nov. The treatment solution contained 250 mg paclobutrazol/liter and 0.05% Tween 20. The medium surface was not covered during treatment to simulate commercial conditions. Each plant received an average of 10 ml of paclobutrazol solution.

To determine the effects of various concentrations of paclobutrazol on flowering, additional plants with 0.5- to 1.5-cm-long inflorescences were selected on 18 Nov. Groups of 10 plants each received paclobutrazol (mg·liter^{-1}) at 125, 125 twice, 250 twice, or 500 once. We applied the second retardant 1 week after the first. Nontreated control plants and plants receiving 250 mg·liter^{-1} once in the previous experiment were included for comparisons. All plants were arranged in a randomized complete-block design replicated 10 times.

Recollected the following data in mid-Mar. 1993: width of the first flower, number of flowers, length of the stalk, internode length between the first two flowers, and diameter of flower stalk measured at the middle of the fourth internode. Duncan's multiple range test was used for comparing treatment effects.

Results and Discussion

First season. Dipping the entire plant in daminozide before planting delayed flowering by 5–13 days (2500 and 7500 mg·liter^{-1}, respectively); foliar application had no effect (Table 1). Paclobutrazol or uniconazole dips did not affect the bloom date, but effectively restricted stalk elongation. Foliar applications of the two retardants produced limited, but statistically significant, effects. The paclobutrazol dip increased and the uniconazole spray slightly decreased the floral internode length (Table 1). Flower quality (e.g., flower size and number and stalk diameter) were unaffected (data not presented). Similarly, uniconazole and paclobutrazol had no effect on hibiscus *Hibiscus rosa-sinensis* L. flower size (Wang and Gregg, 1991). Following paclobutrazol or uniconazole treatments, roots were thicker (observation only). There was no statistical difference in the number of lateral inflorescences between treatment and control plants (Table 1).

By Aug. 1992, all plants treated with uniconazole or paclobutrazol dip at 200 or 400 mg·liter^{-1} produced small, thick leaves. All treatments, with the exception of daminozide dips, increased leaf count (Table 1). On plants treated with daminozide and low rates of paclobutrazol, new leaves had round tips.

Second season. Inflorescence emergence during the second blooming season was not affected by daminozide, but it was progressively delayed by increasing concentrations of paclobutrazol and uniconazole (Table 2). Although not compared statistically, dipping plants in uniconazole solution caused a substantial delay in inflorescence emergence compared to a foliar spray of equal concentration, possibly due to increased retardant uptake.

Regression and contrast analyses showed that retardant affected neither flower size (data not shown) nor main inflorescence flower count (Table 2). All plants previously treated with retardants, except daminozide, had shorter stalks than controls. Plants sprayed with daminozide had longer stalks than nontreated plants. Dipping in uniconazole resulted in thinner stalks.

Daminozide had no effect on leaf size or count, but leaf count was increased by dipping plants in paclobutrazol or spraying with paclobutrazol or uniconazole (Table 2). Uniconazole dip accelerated leaf production at all concentrations except at 200 mg·liter^{-1}. Regardless of application method, plants treated with paclobutrazol or uniconazole had progressively smaller leaves as concentration increased. The effect of uniconazole on restricting leaf size was particularly prominent.

Stage effects. When paclobutrazol was applied before the inflorescences were visible, the stalk length was 45% that of the control, whereas stalks were only 17% shorter when treated at the 10-cm stage (Table 3). Therefore, as treatment was delayed from preemergence of the inflorescences until the 10-cm stage, paclobutrazol progressively restricted stalk elongation less. Delaying treatment until inflorescences were ≥5 cm increased flower size slightly (Table 3). Paclobutrazol treatments did not affect the average number of flowers.

Table 1. The effect of three growth retardants and their method of application on *Phalaenopsis* orchid flowering.

Retadant rate (mg·liter^{-1})	Days to first flower opening[y]	Inflorescence length: Base to first flower (cm)	Inflorescence length: Total (cm)	Flower internode length[z] (cm)	No. laterals	No. new leaves
Control						
0	117	44.7	65.7	3.8	0.0	2.1
			Preplant dip			
Daminozide						
2500	122	48.2	72.5	4.6	0.8	2.3
5000	126	44.1	66.2	3.8	0.5	2.4
7500	130	46.3	71.2	4.1	0.8	2.9
Significance[x]	L***	NS	NS	NS	NS	NS
Paclobutrazol (P)						
50	115	35.2	59.5	4.4	0.1	3.6
100	122	29.5	55.2	4.7	0.4	3.8
200	116	26.3	51.2	4.4	0.5	4.0
400	119	21.5	45.2	4.0	0.3	4.0
Significance	NS	L***Q*	L**	Q*	NS	L*Q*
Uniconazole (U)						
25	114	26.5	51.5	4.3	0.5	3.4
50	118	23.7	47.8	4.8	0.5	3.6
100	117	23.8	47.7	4.1	0.9	3.9
200	120	17.2	39.0	4.0	0.3	2.0
Significance	NS	L***Q**	L***	NS	NS	Q**
P vs. U	NS	**	**	NS	NS	NS
			Foliar spray			
Daminozide						
2500	116	47.7	69.9	4.1	0.5	3.1
5000	124	49.4	72.9	4.4	0.8	3.0
Significance	NS	NS	NS	NS	NS	L*Q**
Paclobutrazol						
250	115	38.6	62.4	3.7	0.3	3.0
500	115	41.8	67.8	3.9	0.1	4.5
Significance	NS	Q*	NS	NS	NS	L***
Uniconazole						
100	116	40.6	63.6	3.6	0.4	4.2
200	117	38.6	60.1	3.2	0.5	3.8
Significance	NS	L*	NS	L*	NS	L**Q**

[z]Internode length between first and second flower.
[y]Begining 13 Oct. 1991.
[x]L= linear; Q = quadratic.
NS,*,**,*** Nonsignificant or significant α = 0.05, 0.01, or 0.001, respectively.

Paclobutrazol also restricted internode length between the first two flowers. Its effect was greater when the applications were progressively delayed (Table 3). Perhaps the limited mobility of paclobutrazol molecules in plant tissues decreased the ability to restrict elongation when applied early (Barrett and Bartuska, 1982; Wang, 1991). Paclobutrazol did not affect the stalk diameter.

Early stage, *Phalaenopsis* inflorescence elongation may result primarily through cell division. Therefore, early growth retardant application exerts a greater effect by limiting the number of cells. Daminozide limited the cell count of chrysanthemum *[Dendranthema × grandiflorum* (Ramat.) Kitamura] internode to one-third that of a nontreated plant (Jin et al., 1992). Uniconazole also curtails cell count and size, resulting in short hibiscus pedicels (Wang and Dunlap, 1994).

Concentration effect. Neither the number of paclobutrazol applications at 125 to 500 mg·liter^{-1} nor the paclobutrazol concentration had an effect on flower size or number (Table 4). Stalk length was restricted in all treated plants, with little dosage effect. The internode length between the first two flowers was shorter as the result of one paclobutrazol application at all concentrations. Surprisingly, two applications had no effect. Also, paclobutrazol concentrations had no effect on stalk diameter (Table 4).

Because plants produced inflorescences uniformly, plants of various stages had to be selected and treated on several dates. This procedure invalidated evaluation of paclobutrazol on bloom date in the second experiment. However, plants treated at the pre-emergence stage, resulting in the shortest stalk, bloomed at the same time as the nontreated plants (Table 3). Therefore, as observed in the first experiment, paclobutrazol treatments probably did not accelerate or delay flowering in the current season.

This study demonstrates that paclobutrazol and uniconazole successfully control *Phalaenopsis* inflorescence length without affecting visual flower quality. However, when used at high concentrations, these substances will delay or prevent the following year's bloom, as well as cause the production of more small, thick leaves. Daminozide is not suitable for controlling the inflorescence length of *Phalaenopsis.*

Table 2. Effect of three growth retardants on second-year performance of *Phalaenopsis* orchids.

Retardant rate (mg·liter^{-1})	Inflorescence emergence (days)[y]	First flower bloom (days)[y]	No. flowers	Stalk[z] Length (cm)[x]	Stalk[z] Diam (mm)[w]	No. new leaves	Uppermost fully expanded leaf Length (cm)	Uppermost fully expanded leaf Width (cm)
Control								
0	48	139	10.0	57.8	6.58	4.3	23.4	10.4
Preplant dip								
Daminozide								
2500	43	138	12.1	62.5	6.48	4.5	21.6	10.6
5000	51	150	10.1	57.9	6.41	4.6	18.8	10.0
7500	36	133	11.0	58.5	6.45	4.4	21.1	10.1
Significance	NS	NS	NS	NS	NS	NS	NS	NS
Paclobutrazol (P)								
50	47	139	10.8	53.4	6.40	4.8	20.5	10.8
100	55	151	10.3	54.1	6.10	6.0	19.3	10.5
200	75	170	10.7	46.9	6.23	6.3	21.0	10.7
400	91	177	10.4	33.2	6.01	6.0	12.8	9.9
Significance[v]	L***	L**	NS	L***	NS	L*Q*	L***	NS
Uniconazole (U)								
25	94	183	9.0	28.0	5.24	5.8	10.6	9.5
50	103	192	9.5	31.7	5.73	7.0	11.0	10.0
100	109	192	9.0	24.7	5.53	6.2	6.4	7.0
200	100	194	8.8	23.9	4.98	4.8	8.4	8.2
Significance	L**Q***	L**Q**	NS	L***Q***	L**	Q*	L***Q***	L*Q*
P vs. U	***	***	*	***	**	**	***	***
Foliar spray								
Daminozide								
2500	30	116	11.9	58.1	6.36	5.1	23.8	10.5
5000	36	133	11.6	67.6	6.95	4.4	23.7	10.1
Significance	NS	Q*	NS	L*	NS	NS	NS	NS
Paclobutrazol								
250	72	163	10.3	49.4	6.05	4.7	22.0	11.1
500	90	181	10.8	48.9	6.36	7.4	17.6	11.3
Significance	L***	L***	NS	L*	NS	L***	L**	NS
Uniconazole								
100	83	170	10.1	43.4	6.16	6.7	15.3	11.0
200	80	169	9.3	35.4	6.09	6.9	8.9	9.0
Significance	L*	L*	NS	L***	NS	L**	L***	NS

[z]Stalk refers to the part of an inflorescence below the first flower.
[y]Day 0 = 1 Sept. 1992 (the date that the first inflorescence started to emerge).
[x]Length from plant attachment to first flower.
[w]Diameter is between the third and fourth internode.
[v]L= linear; Q = quadratic.
NS,*,**,*** Nonsignificant or significant at $\alpha = 0.05$, 0.01, or 0.001, respectively.

Table 3. Effect of paclobutrazol at 250 mg·liter^{-1} on *Phalaenopsis* orchid flowering when treated at various stages of flower spike development.[z]

Stage or length of flower spike (cm)	Inflorescence Length[y] A (cm)	Inflorescence Length[y] B (cm)	Inflorescence Diam (mm)	First flower Bloom[x] (days)	First flower Width (cm)
Pre-emergence	22.1 f	4.5 b	5.9 ab	94.0 a	10.2 c
Emergence	27.8 e	4.3 b	5.6 ab	87.7 b	10.2 c
1.0	31.5 d	4.2 bc	5.6 b	78.5 e	10.3 c
2.5	35.5 c	3.9 cd	5.5 b	87.8 b	10.2 c
5.0	37.8 bc	3.9 cd	6.0 a	81.4 de	10.6 ab
7.5	39.0 b	3.7 de	5.7 ab	87.1 bc	10.4 bc
10.0	40.5 b	3.5 e	5.8 ab	84.3 cd	10.6 a
Control	48.7 a	4.9 a	5.8 ab	93.5 a	10.2 c

[z]Mean separation within columns by Duncan's multiple range at $\alpha = 0.05$. Differences in flower count (7.9–8.9) were nonsignificant.
[y]A = distance between the base and the node bearing the first flower; B = internode length between the first two flowers.
[x]Day 0 = 5 Nov. 1992.

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Table 4. Effect of paclobutrazol at various concentrations on the flowering response of *Phalaenopsis* orchids.[z]

Rate (mg•liter^{-1})	First flower Bloom[y] (days)	First flower Width (cm)	No. flower	Inflorescence Length[x] A (cm)	Inflorescence Length[x] B(cm)	Inflorescence Diam[w] (mm)
0	93.5 a	10.2 a	8.1 a	48.7 a	4.9 a	5.8 ab
125	83.8 b	10.1 a	8.3 a	35.9 b	4.4 b	5.8 ab
125 × 2	81.1 bc	10.1 a	8.1 a	35.5 b	4.8 a	5.5 b
250	78.5 c	10.3 a	7.9 a	31.5 c	4.2 b	5.6 b
250 × 2	79.6 bc	10.2 a	8.7 a	36.2 b	4.8 a	6.0 a
500	80.0 bc	10.3 a	8.2 a	33.5 bc	4.1 b	5.8 ab

[z]Mean separation within columns by Duncan's multiple range test at $\alpha = 0.05$.
[y]For 0 and 250 mg•liter^{-1}, day 0 = 5 Nov. 1992; for all others, day 0 = 18 Nov. 1992.
[x]A = distance between the base and the node bearing the first flower; B = internode length between the first two flowers.
[w]Measured at the middle of the fourth internode.

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