Growth Stage and Site of Application Affect Efficacy of Uniconazole and GA₃ in Hibiscus

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Abstract. Leaf blades, axillary buds, shoot tips, green bark, suberized bark, or the whole plant of container-grown *Hibiscus rosa-sinensis* L. cv. Jane Cowl were treated with uniconazole. Applying uniconazole (50 mg-liter⁻¹) to axillary buds or the green bark below a bud immediately after pruning limited elongation of the first three internodes. Length of the fourth internode was unaffected, regardless of the site of uniconazole application. When used on plants with 24-day-old shoots, uniconazole (40 mg-liter⁻¹) applied to the whole plant provided the only satisfactory height control. Leaf size was reduced by nearly 50%, with a concomitant increase (12%) in fresh weight per unit area. GA₃ (50 mg-liter⁻¹) was more effective in promoting elongation of shoots previously retarded with a drench application of uniconazole (0.1 mg/2.6-liter pot) when applied to the whole shoot, leaf blades, or shoot tip. Application of GA₃ only to the stem surface, whether old or young, did not effectively encourage the growth of shoots of plants previously treated with uniconazole. Chemical names used: (E)-1-(p-chlorophenyl)-4,4-dimethyl-2-(1,2,4-triazole-1-yl)-1-penton-3-ol (uniconazole); analogue of (1 α ,2 β ,4 α ,4 β ,10 β)-2,4a,7-trihydroxy-1-methyl-8-methylenegibb-3-ene-1,10-dicarboxylic acid 1,4a-lactone (GA₃).

Precise height control is important in the production of high-quality potted flowering plants (Bailey, 1989; Wang, 1987). Paclobutrazol has been found to be effective in reducing stem elongation in many plant species (Barrett and Nell, 1989; Mansour and Poole, 1987; Wang and Blessington, 1990). Another growth retardant, uniconazole, can be applied at lower rates than paclobutrazol to obtain similar reduction of stem growth (Barrett and Nell, 1989; Wang, 1989; Wang and Blessington, 1990). Barrett and Bartuska (1982) reported that the effect of paclobutrazol on stem elongation depends on the site of application. Although studies have shown that uniconazole, similar to its analog paclobutrazol (Wang et al., 1986), is translocated in the xylem once it is absorbed by the roots (Sterrett, 1988), much of the information regarding the mode of action of uniconazole is inferred from research conducted on paclobutrazol.

GA may be used to stimulate growth of plants that have been treated with growth retardants (Armitage, 1986; Davis et al., 1988). However, it is not known if GA is uniformly absorbed by various parts of the plant and translocated to regions that are capable of undergoing rapid growth.

The objectives of this study were to characterize the response of hibiscus to the application of uniconazole at specific sites at two growth stages and to evaluate growth in

response to the application of GA₃ to several plant parts of shoots previously retarded by uniconazole.

Rooted cuttings of 'Jane Cowl' hibiscus were planted in 1.5-liter pots filled with a commercial medium consisting of Canadian sphagnum peat, perlite, vermiculite, and fine ground clay (Sunshine Mix No. 1; Fisons Western, Vancouver, B. C., Canada). Plants were grown in a greenhouse under 950 μ mol·s⁻¹·m⁻² maximum photosynthetic photon flux and fertilized with 1.5 g of a 20N-8.6P-16.7K water-soluble fertilizer/liter (W.R. Grace & Co., Fogelsville, Pa.) at each irrigation. The maximum day and minimum night temperatures were 39C and 24C, respectively. Plants were pinched twice to induce lateral shoot development. Three uniform lateral shoots, each having six to seven leaves, were selected from each plant and pruned above the fourth node on 5 May 1989. All other shoots were removed. By this time, the bark on stems that developed after the first pinch had suberized. A water solution

containing uniconazole at 50 mg-liter⁻¹ and 0.1% Tween 20 was applied with a brush to the adaxial side of the leaves, the uppermost axillary bud of each shoot, the green bark (stem surface) below the uppermost nodes, or the suberized bark below the base of selected shoots. Control plants received no treatment. After 5 weeks, the length of each of the lowest four internodes of each uppermost axillary shoot was measured. Node number bearing the first flower was recorded for each shoot.

Another set of plants was grown as described above. On 9 Sept. 1989, 24 days after the third pruning, four lateral shoots with an average of four leaves were selected on each plant and the others removed. Stem length and leaf number were recorded for each shoot. An aqueous solution containing uniconazole at 40 mg-liter⁻¹ with 0.1% Tween 20 was applied with a brush to the adaxial side of all new leaves >2 cm, the green bark, the suberized bark, or the whole plant. Another treatment consisted of placing a drop of the uniconazole solution on shoot tips. Untreated plants served as controls. Three weeks following GA₃ application, new shoot growth, number of new leaves, and area (measured with a LI-COR 3100 area meter; LI-COR, Lincoln, Neb.) and fresh weight of the sixth leaf from the base were recorded for each shoot. This leaf had developed under the influence of applied uniconazole and had fully matured at the time of data collection. The maximum day and minimum night temperatures were 37C and 19C, respectively.

A third group of plants was grown in 1.5-liter pots as above, pruned twice, and transferred to 2.6-liter pots. All plants received a soil drench of 250 ml water solution containing 0.1 mg uniconazole 6 weeks after transplanting. Plants were pruned after 7 days and allowed to grow for another 4 weeks. On 5 Dec. 1989, three uniform shoots were selected from each plant, labeled, and their lengths measured from the base to the uppermost visible node. An aqueous solution containing GA₃ (Sigma, St. Louis) at 50 mg-liter⁻¹ and 0.05% Tween 20 was applied with a brush to the surface of a single internode below the axillary branch (old stem), the green bark of axillary shoots (young stem), the adaxial side of leaf blades, or the entire shoot of selected shoots. In another treatment, shoot tips each received one drop of

Table 1. Effect of uniconazole (50 mg-liter⁻¹) on hibiscus shoot growth during 5 weeks when applied at various sites immediately after pruning.^a

Site of application	Internode length (cm)				Total length of first three internodes	Node bearing the first flower
	Internode no. 1	Internode no. 2	Internode no. 3	Internode no. 4		
Control	1.1	2.9	3.0	3.9	7.0	6.1
Leaves only	0.9	2.2	2.5	3.8	5.6	5.8
Suberized bark	1.1	2.0	2.2	3.1	5.3	5.9
Buds only	0.5	0.7	1.5	4.2	2.7	5.1
Green bark ^b	0.5	0.6	1.5	3.9	2.6	5.1
HSD _{0.05}	0.5	0.7	0.8	0.9	1.4	0.8

^aMeans are averages of three replicates each with three selected shoots.

^bTreatment was applied only to the green bark below the uppermost node.

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Table 2. Effect of uniconazole (40 mg-liter⁻¹) on hibiscus shoot growth during 3 weeks when applied at various sites after plants were pruned and lateral shoots had an average of four leaves.*

Site of application	Stem elongation (cm)	Leaf area (cm ²) ^y	Leaf fresh wt (mg·cm ⁻²)
Control	11.3	80.0	37.9
Shoot tip	10.8	78.8	37.5
Suberized bark	10.8	75.3	38.6
Leaves	9.9	74.4	36.6
Green bark	9.4	81.4	37.5
Whole plant	3.5	41.5	42.3
HSD _{0.05}	1.9	14.4	2.5

*Means are averages of three replicates each with four selected shoots.

^yArea of the sixth leaf from the base.

Table 3. Effect of site of GA₃ (50 mg-liter⁻¹) application on promoting the growth of hibiscus shoots previously treated with a soil drench of uniconazole (0.1 mg/pot). Shoots were allowed to grow for 6 weeks before data collection.*

Site of application	Stem elongation (cm)	Pedicle length (cm)
Control	0.7	3.0
Old stem	1.3	3.3
Young stem	1.4	3.5
Leaf blades	3.4	7.2
Shoot tip	3.8	8.0
Whole shoot	4.9	8.8
H S D _{0.05}	1.8	2.0

*Means are averages of three replicates each with three selected shoots.

the GA₃ solution. Control plants received no treatment. All flower buds >2 cm were removed. The amount of shoot growth and pedicle length of the first flower bud were recorded after 6 weeks. The temperature range was 10 to 35°C.

In all experiments, a single plant in a pot served as an experimental unit and treatments were replicated three times in a randomized complete-block design. Tukey's *w* procedure (HSD) was used to determine treatment effects.

Application of uniconazole to lateral buds or to the green bark immediately after pruning effectively controlled the elongation of the first three internodes (Table 1). Application to leave: or the suberized bark resulted in no or a limited effect, respectively. Uniconazole did not control stem elongation beyond the third internode, possibly due to the small amounts applied and/or the limited mobility of uniconazole molecules in plant tissues (Sterrett, 1988). The two most effective treatments also induced flower buds to be produced on a lower node than in the control (Table 1).

When uniconazole was applied to young, actively growing shoots 24 days after the third pruning, the most effective control of stem elongation was by application to the whole plant (Table 2). This treatment also reduced leaf area by nearly 50%, with a concomitant 12% increase in fresh weight per unit area. Treating leaves or green bark had a smaller effect on suppressing internode elongation, yet induced statistically significant effects.

Barrett and Bartuska (1982) reported that application of paclobutrazol to stems of bean

and chrysanthemum resulted in shorter shoots than untreated plants. However, in the current study, application of uniconazole to the green bark of actively growing hibiscus shoots did not provide satisfactory height control. The discrepancy between the two studies might have been due to the difference in concentrations of the two retardants. Paclobutrazol was applied to stems of bean and chrysanthemum at 75 and 150 mg-liter⁻¹ (Barrett and Bartuska, 1982), respectively, whereas in this study, uniconazole was used on hibiscus at 50 and 40 mg-liter⁻¹ and may have resulted in insufficient amounts being absorbed and translocated to the target sites. The difference in the structure of stem tissues between the herbaceous chrysanthemum and bean and the woody hibiscus may have also affected the absorption of retardants.

Differences in plant response to the application of uniconazole at various sites possibly were due to the amount of compound being applied, absorbed, and subsequently translocated to the sites of active elongation. Once uniconazole is in the plant system, only a small portion moves to the site of new growth through the transpirational stream (Numbere et al., 1989; Sterrett, 1988). Uniconazole was reported to have little or no control over the shoot length of cuttings taken from plants that had previously received a soil drench of this compound (Wang and Gregg, 1989). Paclobutrazol remained in the lower section of the peach stem after being absorbed by the root system (Early and Martin, 1988). These results might explain why uniconazole only restricted the elongation of the first three internodes in the first experiment. Since application of uniconazole to the leaves had a limited effect on shoot elongation, this compound possibly is similar to paclobutrazol in having only limited movement in plants (Early and Martin, 1988). In this study, application of uniconazole to the whole plant probably supplied the greatest amount of active ingredient for absorption and translocation to the upper shoot, providing an effective and longer-lasting height control. Uniconazole was very stable in apple shoots within the first 4 weeks following application (Sterrett, 1988) and provided long-term height control of treated hibiscus (Wang and Gregg, 1989).

Applying GA₃ to the stem surface, whether to old or young stems, did not effectively

promote new growth (Table 3), suggesting a problem in absorption or translocation of GA₃ applied to the bark. Application of Promalin (a mixture of equal concentrations of GA₄₊₇ and benzyladenine) to the bark of sweet cherry trees did not restore the inhibition of stem elongation brought about by paclobutrazol (Jacyna et al., 1989). Hibiscus shoot growth was nearly five- to six-fold that of the controls when GA₃ was applied to either the leaf blades or to the shoot tip. Treating the entire shoot with GA₃ resulted in the most rapid shoot growth. GA₃ also triggered the flower pedicel to elongate. Wample and Culver (1983) reported that application of GA₃ at 40 mg-liter⁻¹ to the whole plant of sunflower 2 days after the application of paclobutrazol completely eliminated the effect of paclobutrazol on plant growth. Results of the current experiment suggest that foliarly applied GA₃ could be effectively absorbed and translocated out of the leaves via the phloem to zones of elongation to induce rapid shoot growth.

Results of this test suggest that uniconazole only suppressed the biosynthesis of GA and did not interfere with the biological effect of exogenously applied GA (Law and Hamilton, 1989). Since leaves at all ages were treated in this study, it is not clear whether both the mature and expanding leaves were capable of exporting the exogenously applied GA₃.

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