SECTION 7
GROWTH REGULATORS

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A Leaching Frame For Determining Media Retention of Drench-Applied Plant Growth Regulators

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Nature of Work: Height control is the foremost problem in growing poinsettias. Most cultivars would not meet the height or size requirements without cultural practices that regulate growth. The majority of growers in the mid-south pinch poinsettias to control final height, but this alone does not always have the desired effect; chemical plant growth regulators are often used to attain the desired height control in poinsettias (Hartley, 1992). Several other species of potted flowering plants are also treated with chemical plant growth regulators applied as a drench. Some of these chemical plant growth regulators require very small rates of application. The activity of these regulators is influenced by the base organic material and particle size of the media (Barrett, 1982; Lamont, 1986; Quarrels and Newman, 1994). Considering the wide variety of media used to grow poinsettias and other flowering potted plants, there is a need for further research to study the effects of growing media on the activity of growth regulators.

A leaching frame was constructed to facilitate detection of residual amounts of chemical plant growth regulators and determine, based on the type growing media, 1): if growth regulators leach at different rates; 2): if growth regulators are bound to the surface of the media components; and 3): if so, are the growth regulators bound at the upper, middle or lower levels of the container media.

The leaching frame supporting legs were constructed of 2 x 4 inch treated lumber. The lower bench platform was made of exterior grade plywood 3ft x 6ft x 3/ 4in, the upper bench platform of 3ft x 6ft x 1/2in exterior grade plywood. Forty 4 1 /4in diameter holes (4 rows of 10) were bored into the plywood platforms at 3 1 /2in between rows and 2 1 / 2in between columns. The lower platform was secured with wood screws to the supporting legs. Funnels (4 1 /2in diameter at the top) were inserted into the holes of the lower platform for gathering and directing the leachate. To prevent media from falling out of the cylinders, a sheet of woven polypropylene landscape fabric was placed on top of the lower platform over the funnels. Irrigation line (1 6mm thin wall) was then laid on top of the landscape fabric and fastened with clamps to hold in place. Four millimeter spaghetti tubes (40 total) were attached to the irrigation tubing to route water to the top of the cylinders. Holes were drilled into the top platform to allow the spaghetti tubes to be routed above the top of the platform. The top platform was placed on the supporting legs, making a two-tiered table with 11 in between platforms. A 1/2 gal/hour emitter (at 20psi) was inserted into each of the spaghetti tubes. The tube/emitter assembly was held in place over the cylinders by an emitter stake.

Forty polyvinylchloride cylinders (4in diameter x 1 2in length) were cut in half lengthwise with four screws inserted into the lower sides of each cylinder to hold a 1/4 in

hardware screen in place. All cylinders were taped together with duct tape and placed into the holes of the top platform. The cylinders rested on the lower platform above each corresponding funnel.

Cylinders were filled with two media: 2 vermiculite: 1 peat moss: 2 pine bark; or 2 vermiculite: 2 peat moss: 2 pine bark (by volume). Nutrient amendments added to the media were dolomitic limestone at 101b/yd^3 and Micromax at 1 Ib/yd^3.

Rooted cuttings of 'Freedom' poinsettias were planted in the cylinders on August 27,1993. The growth regulators were applied on September 24,1993. The growth regulators used were paclobutrazol and uniconazole at 0.25mg active ingredient/ plant applied in 500ml tap water and a paclobutrazol spike at 0.125mg active ingredient/spike with one spike per plant. A control treatment of 500ml tap water was also applied. There were five single plant replications per each treatment. The plants were fertilized at every irrigation with Excel 15-5-15 Cal/Mag (Grace/Sierra Corp, Foglesville, PA). Plant height was measured on December 18, 1993, and then harvested. Bract surface area was determined using a leaf area meter (Li-Cor, Lincoln, NE). Bracts and stems were dried in a convection oven at 60C for 48 hours to obtain dry weights.

To test for residual growth regulator in the media, the cylinders were cut in half and laid in trays. Plugs of cutflower snapdragon cultivars 'Winchester' and 'Potomac Pink' were planted three to each cylinder half (one plug each at 2, 6, and 1 Oin cylinder depth) on January 11,1994. Plants were fertilized at every irrigation with Excel 15-515 Cal/Mag (Grace/Sierra Corp, Foglesville, PA). Plant height was taken on March 12, 1994.

Results and Discussion: In the poinsettia study, paclobutrazol and uniconazole effectively reduced plant height. The presence of increasing levels of pine bark in the media reduced the effect of all growth regulator treatments. The paclobutrazol spike was not so effective in reducing plant height as compared to the paclobutrazol and uniconazole drench treatments. Uniconazole reduced plant height to a greater extent than the other treatments in either media.

The follow-up study using snapdragon plugs to detect residual growth regulator in the media showed no differences in plant height among media, depth of planting in cylinder, growth regulators, or cultivar. However, in a previous study (unpublished data) residual levels of growth regulator were detected. Cotton seeds were planted at various depths (2,4, 6,8, and 10 inch) in the media after continuous irrigation was applied for seven days. Seedling growth showed residual levels of growth regulator present in the upper depths (2 and 4 inch) of the media. Cotton seedling plant height was reduced in those plants growing at the 2 and 4 inch depths. The leachate was gathered and applied to laboratory-grown cotton seedlings; their growth showed that the leachate contained growth regulator.

Significance to the Industry: Results from this and other studies show that the base organic component and particle size of the growing media effect the activity of chemical plant growth regulators. Some of these growth regulators are applied in very small amounts and reduce plant height effectively. Because of this, growers need to know which components are in the medium they choose. It appears that in media that contain high levels of pine bark, growth regulators are not as effective at reducing plant height as in those media, which contain high levels of peat moss.

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Effect of Atrimmec and Embark Trim-Cut on Growth of Asiatic and Confederate Jasmine

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Nature of Work: Asiatic jasmine (*Trachelospermum asiaticum)* and confederate jasmine (T. *jasminoides)* are woody vines that require costly manual pruning during production to control vegetative growth. Owings et al. (1) showed that runner growth of these species was reduced when Atrinal (currently marketed as Atrimmec; dikegulac) or Embark (mefluidide) were applied to liners growing in 1-gal containers. However, plant growth regulator (PGR) activity can be influenced by plant age (2). The objective of this experiment was to determine the activity of Atrimmec and Embark on confederate and Asiatic jasmine older than those used by Owings et al. (1).

One-gallon containers of 9-month-old Asiatic and confederate jasmine were pruned to a uniform size (within a species) on May 24, 1993 (resulting in an average size (height X width) of 7 X 10.7 inches for Asiatic jasmine and 26.8 X 13.7 inches for confederate jasmine (staked to 6 to 7-foot poles). The plants were grown with overhead irrigation under full sun at the North Florida Research and Education Center in Monticello, Florida. Foliar sprays of Atrimmec (PBI/Gordon, Kansas City, Missouri) at 1, 2, or 3 oz/gal or Embark Trim-cut (PBI/Gordon, Kansas City, Missouri) at 3.25, 6.5 or 13 oz/gal were applied May 25, July 20, and September 15. Unsprayed plants that received no additional pruning served as unpruned controls; unsprayed plants that were pruned July 19 and September 15 served as pruned controls. There were five single-plant replications per treatment arranged in a randomized complete block design (within species). On June 8, all plants were repotted (with minimal disturbance to the root ball) into 3-gal containers. The potting medium was composed of pine bark:Canadian sphagnum peat:sand (3:1:1 by vol.) and amended (per yd3) with 3.8 lb triple superphosphate, 10 lb Osmocote 18-6-12 and 2.4 lb Micromax.

Plant height and two widths (widest point and perpendicular to the widest point) were measured initially and 8 weeks after the third application. Foliar phytotoxicity was evaluated at 1, 2, and 8 weeks after each application. Injury was rated on a 0 to 100 scale (increments of 10) with 0=no injury and 100 = plant death.

Results and Discussion: *Asiatic jasmine.* Atrimmec at 2 and 3 oz/gal significantly reduced horizontal runner growth (width) through November 10, 1993 (24 weeks) while Embark Trim-Cut was ineffective (Table 1). All treatments caused slight foliar injury (chlorosis and/or distortion) to the new growth (i.e., leaves that developed after spraying) and unexpanded foliage for 2 to 4 weeks after the initial application (Table 1). Slight foliar damage generally lasted 1 to 2 weeks following the second and third applications from all the Embark Trim-Cut treatments and Atrimmec at 1 oz/gal. The two higher concentrations of Atrimmec caused lasting foliar injury that was concentration dependent and carried over from one application to the next.

Confederate jasmine. Atrimmec at 2 and 3 oz/gal reduced increases in height and/or width of staked confederate jasmine for 24 weeks; however, the 3 oz/gal treatment suppressed nearly all growth and caused excessive foliar distortion to the new growth and unexpanded foliage (Table 1). Slight chlorosis and/or foliar distortion persisted from 2 through 8 weeks after the initial treatment on plants treated with 2 or 3 oz/gal Atrimmec. Injury severity increased after the second and third applications of Atrimmec at 2 and 3 oz/gal and seemed to be a cumulative effect.

Atrimmec at 1 oz/gal and all rates of Embark Trim-Cut were ineffective in controlling growth. Plants receiving these treatments had to be pruned on July 19 and September 15 due to excessive growth. Minimal chlorosis was evident 8 weeks after the initial application of Atrimmec at 1 oz/gal, with a slight increase in injury from the first to the second application. However, since the plants were pruned before the third application, there was no increase in phytotoxicity from 8 weeks after the second application to 8 weeks after the third application.

Significance to Industry: Manual pruning of Asiatic and confederate jasmine during production can be virtually eliminated by the use of Atrimmec at 2 oz/gal at 8-week intervals. Embark Trim-Cut was not an effective PGR on either jasmine species.

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Table 1. Effect of Trim-Cut and Atrimmec applied at 8-week intervals on container-grown Asiatic and confederate jasmine.

Treatment[y]	Amt oz/gal)	Injury rating[z] (weeks after 1st appl.) 1	2	4	8	(weeks after 2nd appl.) 1	2	4	8	(weeks after 3rd appl.) 1	2	4	8	Total growth increase May 25 to Nov. 10, 1993 Ht(in)	Wd(in)
ASIATIC JASMINE															
Unpruned Control	-	0	0	0	0	0	0	0	0	0	0	0	0	1.3	39.8
Pruned Control	-	0	0	0	0	0	0	0	0	0	0	0	0	2.3	42.1
Trim-Cut	3.25	16	14	0	0	20	4	0	0	4	8	0	0	1.7	36.1
Trim-Cut	6.50	14	12	0	0	18	8	0	0	4	6	0	0	1.0	39.4
Trim-Cut	13.00	14	6	0	0	24	10	0	0	10	10	2	0	1.5	35.9
Atrimmec	1.00	8	8	0	0	10	2	0	0	4	8	0	2	1.1	40.5
Atrimmec	2.00	6	4	4	0	18	16	12	12	20	26	24	18	1.8	23.2
Atrimmec	3.00	10	8	10	8	30	36	34	32	36	38	38	38	0.8	10.6
LSD α=0.05		5	7	2	2	7	6	3	3	6	7	5	5	1.0	6.8
CONFEDERATE JASMINE[x]															
Unpruned Control	-	0	0	0	0	0	0	0	0	0	0	0	0	29.2	16.1
Pruned Control	-	0	0	0	0	0	0	0	0	0	0	0	0	19.8	26.4
Trim-Cut	3.25	0	0	0	0	0	0	0	0	0	0	0	0	18.9	17.8
Trim-Cut	6.50	2	4	0	0	0	0	0	0	0	0	0	0	24.0	21.6
Trim-Cut	13.00	0	0	0	0	0	0	0	0	0	0	0	0	18.1	14.1
Atrimmec	1.00	0	0	0	2	4	10	10	8	2	10	8	2	17.2	19.1
Atrimmec	2.00	0	2	6	4	24	24	24	28	30	30	38	36	9.9	15.0
Atrimmec	3.00	0	4	6	12	34	34	34	38	42	50	52	50	1.2	1.0
LSD α=0.05		2	4	4	5	6	6	6	5	7	7	6	3	8.7	9.0

[z] Injury rating 0-100 in increments of 10; 0 = no injury and 100 = plant death.
[y] Five replications per treatment.
[x] Due to excessive growth, all confederate jasmine treated with Atrimmec at 1.0 oz/gal or Trim-Cut were pruned immediately prior to the second (July 20) and third (September 15) application.

Method of Application Affects Response of Hollyhock (*Alcea rosea*) to Bonzi

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Nature of Work: Interest in reducing the amounts of pesticides applied to ornamental crops and the increasing concern about applicator safety prompted this research to examine low volume or low exposure methods of applying plant growth regulators (PGRs). Bonzi (paclobutrazol, Uniroyal Chemical) is generally applied at low rates and thorough stem coverage is required for efficaceous spray applications. Bonzi also is soil active.

Hollyhock ('Powderpuff Mix') plants established in 10-cm pots from plugs were purchased from a commercial source on 14 Sept. 1993. Bonzi was applied on 24 Sept. 1993. Application methods included high (500 ml/m^2) and low (210 ml/m^2) volume sprays with a hand-held compressed-air sprayer; spray application with a hand-held electrostatic sprayer or a fixed-position fog sprayer; a drench of 50 ml of 2 ppm Bonzi per pot; and a Bonzi spike cut into quarters and two pieces placed on opposite sides of the plant. Treatments were designed to apply 0.10 mg/pot except with the high volume spray (0.25 mg/pot) and the spike (0.12 mg/pot). This rate is equivalent to a Bonzi spray application of 50 ppm at the label volume of 2 qts/100 ft^2. After treatment, plants were arranged in a randomized complete block design with five replications. At 2, 4 and 6 weeks after treatment, number of leaves and height of the new growth (plant height) were measured. At 6 weeks after treatment, the plants were moved to a cold frame for overwintering. Dormant plants were planted in the landscape in February 1994. Plant height and flower evaluations were measured in June 1994.

Results and Discussion: The higher rate of application of paclobutrazol with the compressed air high volume (0.25 mg/pot) resulted in the shortest plants, with significant reductions in growth at 2 weeks after treatment (Table 1). The compressed air low volume spray resulted in a 36% reduction in plant height at 6 weeks after treatment. However, the number of leaves was nearly twice that of the untreated control plants. The drench and spike treatments resulted in 40% and 54% reductions in plant height, respectively, at 6 weeks after treatment. Both treatments also increased the number of leaves at 6 weeks. The electrostatic and fog treatments did not significantly reduce plant height or increase number of leaves formed. No signs of phytotoxicity were observed. Only treatment with the high volume compressed air sprayer or the electrostatic sprayer reduced plant height and delayed flowering in the landscape the summer following treatment (Table 2).

Significance to the Industry: The results of this study suggest that low volume (electrostatic) and ultra-low volume (fog) spray applications are not efficacious for PGR applications. Perhaps, the growth habit of hollyhock, a rosette with primarily petioles and leaves exposed to treatment, would not present sufficient active sites for Bonzi absorption under the low or ultra-low volume applications. Again, growers should be reminded of the potential for persistent effects of Bonzi in the landscape.

Table 1. Effect of Bonzi (paclobutrazol) on number of leaves developed and height of new growth of Hollyhock at 2, 4, or 6 weeks after treatment (n = 10). All application techniques were designed to deliver 0.10 mg paclobutrazol per 10-cm pot except compressed air high volume (HV) which aplied 0.25 mg/pot and spike which applied 0.12 mg/pot.

	2 wk		4 wk		6 wk	
Treatment	Number of leaves	Plant height (cm)	Number of leaves	Plant height (cm)	Number of leaves	Plant height (cm)
Untreated	8.5 abcd[z]	4.6 a	17.6 b	21.8 a	15.2 c	20.2 a
Compressed air-LV	8.3 bcd	3.4 bc	22.3 a	10.0 c	29.0 a	13.0 b
Compressed air-HV	6.8 d	2.6 c	17.9 b	5.6 d	25.5 ab	7.1 d
Electrostatic	9.1 ab	4.4 ab	18.1 b	19.8 a	19.9 bc	21.1 a
Fog spray	9.0 abc	4.4 ab	17.9 b	16.4 b	17.6 c	18.7 a
Drench	7.3 cd	3.4 bc	20.0 ab	8.8 c	27.1 a	12.0 bc
Spike	10.2 a	3.1 c	21.3 a	7.6 cd	30.5 a	9.2 cd

[z] Mean separation by protected LSD, P < 0.05.

Table 2. Residual effect of Bonzi on hollyhock growth and flowering in the landscape. Plants were planted Feb. 1994, and measured 22 June 1994 (n = 10).

Treatment	Plant height (cm)	Flower development[z]
Untreated	146 a[y]	4.0 a
Compressed air-LV	135 a	3.6 ab
Compressed air-HV	80 c	1.3 c
Electrostatic	83 bc	1.8 bc
Fog spray	136 a	4.0 a
Drench	126 abc	3.7 ab
Spike	129 ab	2.4 abc

[z] Scale 0 = no buds, 1 = tight, unopened buds, 2 = buds showing color, 3 = less than 50% flowers open, and 4 = more than 50% flowers open.

[y] Mean separation by protected LSD, P < 0.05.

Growth Management in Commercial Production of Bedding Plants: Pansies *(Viola x Wittrockiana)*

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Nature of Work: Several commercially available plant growth regulators were tested on F_1 hybrid pansy varieties to determine the most effective material and rate of application for the production of compact bedding plants. In a preliminary experiment, the *Viola x Wittrockiana* cvs. 'Universal Deep Yellow', 'Universal Blue with Blotch', 'Universal Yellow with Blotch', 'Universal True Blue', 'Universal Red', 'Universal White', 'Maxim White', 'Maxim Blue', and 'Maxim Red' were grown outside in 6xS in. containers by a wholesale nursery grower in Suffolk, Virginia. All of the pansies were potted in the nursery's standard pine bark mix and maintained by the grower in the same manner as the rest of the crop*. Plants were 2 in. tall at the time of growth regulator application. Treatments were applied on August 20, 1993, with a CO_2 sprayer at 30 psi. The growth regulators tested included A-Rest sprays at 4 and 8 ppm; Sumagic sprays at 3 and 6 ppm; Bonzi sprays at 15 and 30 ppm; a B-nine spray at 5000 ppm, and an untreated control. Treatments were completely randomized with three singleplant replicates per treatment for each cv. Plants were measured on September 8, 1993. Each cultivar was evaluated as a separate experiment.

Growth regulator spray treatments were applied to a second group of pansy cultivars on September 10, 1993. The cultivars treated were 'Universal Yellow with Blotch', 'Universal White', and 'Universal Blue with Blotch'. On this date, A-Rest sprays at 8 and 16 ppm, Sumagic sprays at 6 and 12 ppm, Bonzi sprays at 20, 30, and 40 ppm, and an untreated control were applied to plants which were 3-4 in. tall. A randomized complete block design was utilized with three eight-plant replicates per treatment for each cv. The plants were measured on September 21, 1993, and again on October 1, 1993. Height and width were measured on both dates. Plants were visually rated by the grower on the second date for preferred size and form at time of shipping, with 1 being least desirable and 5 being the most desirable size and form.

Results and Discussion: The preliminary experiment showed little response from the A-Rest and B-Nine treatments at the rates tested. The most effective growth control was with the Sumagic and Bonzi treatments, particularly at the higher rates (data not shown). A second experiment was conducted to include higher rates of A-Rest, Bonzi and Sumagic. Results of this experiment from the October evaluation are presented in Figs. 1, 2, and 3. The relative growth control effectiveness of the eight treatments was very similar across all three pansy cultivars. The most compact plants were produced with 12 ppm Sumagic and 30-40 ppm Bonzi. The least growth control was obtained with the two A-Rest treatments. Grower preference for treatments seemed to depend somewhat on overall growth rate of the three cvs. when choosing the most desirable treatments. 'Universal Blue' had larger plants overall, and the grower preferred the higher rates of Sumagic and Bonzi for this cv. 'Universal Yellow' and 'Universal White' were generally not as large, and the grower preferred the lower rates of Sumagic (6

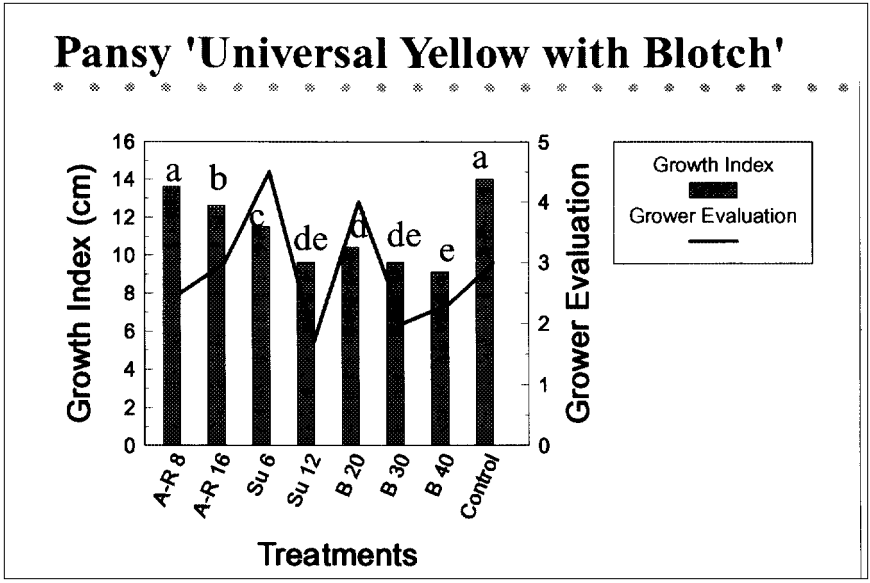
ppm) and Bonzi (20 ppm), indicating the higher rates gave excessive growth control on these cvs.

Significance to Industry: Effective growth regulator treatments reduce the amount of labor required for handshearing bedding plants to keep them compact. Less hand labor means fewer expenses in the production of bedding plants, including pansies.

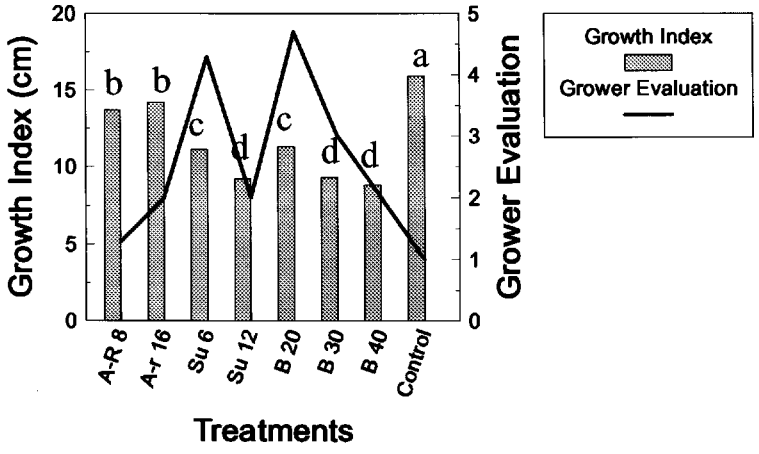
In these experiments, we asked the grower to assist with the final evaluation so that an indication of the most desirable size and form at the time of sale/shipping, from a grower point-of-view, could be provided. For the most rapidly-growing cv. ('Universal Blue with Blotch') 12 ppm Sumagic or 30 or 40 ppm Bonzi were the preferred treatments. For the slightly slower-growing cvs. ('Universal White', 'Universal Yellow with Blotch') 6 ppm Sumagic or 20 ppm Bonzi gave the preferred response, providing compact attractive plants without excessive retardation. These results suggest that cultivar response to growth regulators can be an important factor. Lower rates of Bonzi and Sumagic should be tried first on cvs. that the grower may not be familiar with in terms of growth rate and growth regulator response.

*We would like to express our thanks to Lancaster Farms Nursery, Suffolk, Virginia, for providing plants and research space for this study. We especially thank Mr. Sam Saunders for his assistance in setting up and evaluating the experiments.

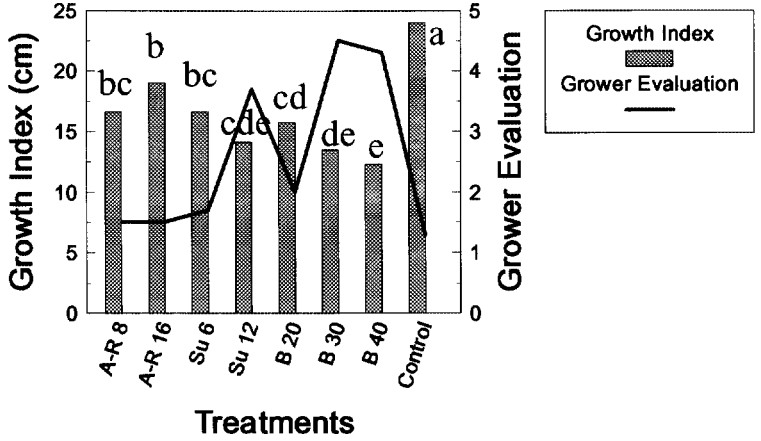
Fig. 1, 2 and 3. Growth indices and grower preference evaluations for growth regulator applications to three pansy cvs. Treatments (left to right): A-Rest 8 ppm, A-Rest 16 ppm, Sumagic 6 ppm, Sumagic 12 ppm, Bonzi 20 ppm, Bonzi 30 ppm, Bonzi 40 ppm, Control. Grower preference rating: 5= desirable size and form at time of sale/shipping.



Pansy 'Universal White'



Pansy 'Universal Blue with Blotch'



Offset Stage of Development Affects Hosta Propagation by Division

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Nature of Work: Hosta is usually propagated in the spring by crown division, a process that produces only a few plants per clump. In an earlier study, rhizomic and axillary buds of hosta treated with the cytokinin BA elongated within 14 days of treatment (1). However, offsets from these buds decreased over time, indicating the abortion of random offsets. Offsets removed in June, following a period of dormancy, formed well-developed root systems within six weeks. Our study was conducted to determine if offsets removed soon after bud elongation could be rooted. If successful, this procedure potentially would shorten the time required to increase stock and avoid the loss of offsets experienced in the earlier study.

Stock plants of *Hosta sieboldiana* were sprayed on July 20, 1993, with 2500 ppm BA to induce offset formation. After 3 1/2 weeks, offsets were removed and divided into four groups based on stage of development (SOD). Half the offsets representing each SOD were treated with a 5-second, quick dip of 1000 ppm K-IBA. Offsets were stuck in 32 - cell flats of Metro 360 medium and placed under intermittent mist. There were eight treatments with six replicates of four offsets each in a randomized complete block design. A description of offset stage follows; SOD l:elongated bud, first leaf furled; SOD 2: one furled and one unfurled leaf; SOD 3: two unfurled leaves; SOD 4: three unfurled leaves. On September 24, 1993, the study was terminated with the collection of the following data: percent rooting, primary and secondary root numbers, root length (mean of three longest primary roots/offset), root rating (0 = no roots, 5 = dense root mass), shoot stage of development (same 4 SOD plus SOD 5: four or five leaves unfurled; SOD 6: six or more leaves unfurled), and root dry weight.

Results and Discussion: All measured characteristics were influenced by offset SOD. Rooting increased from 56% at SOD 1 to 88% at SOD 4, while primary and secondary root numbers and root dry weight were higher at SOD 3 than at SOD 1 or 2 but less than at SOD 4. Both root length and root rating were greater at SOD 3 or 4 than SOD 1 or 2. Shoots continued to develop while offsets were under mist; after six weeks, mean SOD for offsets initially at SOD 1, 2, 3 and 4 were 2.6, 3.3, 4.0 and 4.9, respectively. Of the measured characteristics, K-IBA affected only primary root number. Offsets treated with IBA averaged 10.9 primary roots, while untreated offsets averaged 8.1.

Significance to Industry: Offsets formed from axillary and rhizomic buds stimulated to elongate by BA can be removed and rooted as early as 3 1/2 weeks after treatment. A higher percent rooting and more root development occured when more offset leaves had unfurled. Treatment of offsets with K-IBA appeared to offer minimal benefit.

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Influence of Primo™ on Flower Color of Potted Chrysanthemums

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Nature of Work. Preliminary research with a new turf retardant called cimectacarb or Primo (4-(cyclopropyl-æ-hydroxy-methylene)- 3,5 dioxo-cyclohexane-carboxylic acid ethyl ester, Ciba-Geigy, Greensboro, NC) in 1993 revealed that Primo could influence flower color. Only red-purple (cyanic) colored flowers were affected. White and yellow cultivars were unaffected except for growth retardation. It was speculated that Primow interfered with the anthocyanin necessary for cyanic colors. The color change can be pleasing and can expand the use and marketability of desirable varieties or cultivar. The present work examines the influence of Primo on flower color in chrysanthemum *Dendranthema grandiflora* (Ramat.) Kitamura *(Chrysanthemum x morifolium).* On October 4, 1993, rooted cuttings of the chrysanthemum cultivars 'Lucindo', 'Red Delano', 'Redding', and 'Regal Davis' were planted (four per pot) into 6-inch (15 cm) plastic pots containing (by volume) 2 sphagnum peat moss, 1 pinebark, 1 verrniculite, 1 perlite, and 1 top soil medium amended with 6 oz (168 g) dolomitic limestone, 4 oz (112 g) Osmocote 14-14-14 or 14N-6.1P-11.6K (Sierra Division, The Scotts Company, Marysville, OH), and 1 oz (28 g) Micromax minor element additive (Sierra Division, The Scotts Company, Marysville, OH) per $ft^{3.}$ Standard commercial culture for greenhouse potted chrysanthemums was used (2). Cultivar selection was done on the advice of Ed Higgans of Yoder Brothers, Barberton, OH (personal communication). Plants were grown in full sun at 62°F (17C) minimum night temperature. Supplementary incandescent lighting, 10 PM to 2AM, was used until October 19. When new shoot growth was 1 1l/2 inches (2.5-3.75 cm) and the roots reached the bottom of the pot, the top inch (1.25 cm) of the plant apex was removed (pinched). Peter's Peatlite Special 20-10-20 (20N-4.4P-16.6K by Peter Fertilizer Products, The Scotts Company, Marysville, OH) was applied to the media every two weeks at the rate of 2 Ibs per 100 gal (2.4 g per liter). When the flower buds were l/4-inch (0.6 cm) in diameter, the center bud on a shoot was removed and fertilization stopped. Treatments applied on November 2 were 0, 150, 300 and 600 ppm Primo. The standard chrysanthemum growth retardant, B-Nine (daminozide, Uniroyal Chemical Co., Bethany, CT) was included as a comparison at the rate 5,000 ppm. Treatments were sprayed on the plants until runoff with a low pressure, high volume sprayer. When one-third of the flowers were open on a pot, plant height, canopy area (diameter at the top of the plant measured in two directions and multiplied), flowers per plant, flowering date and quality rating were recorded. Plant quality was rated 1 = very poor, 2 = poor, 3 = average, 4 = good, and 5 = excellent. Analysis of variance regression and contrasts (daminozide vs cimectacarb) were conducted on data to determine significance. Ray floret (petal) color was visually compared to colors appearing in the Exotica Horticultural Color Guide (1) in order to identify a color by a name and a number.

Results and Discussion: Primo influenced ray floret or petal color in all cultivars tested. Color changes were very uniform, consistent with rate, and free of distortion, chlorosis or undesirable growth effects. The most pleasing and probably salable

changes occurred with cvs. 'Lucindo', 'Regal Davis' and, in some instances, 'Redding'. Primo changed the color of 'Lucindo' ray florets from a blood 27 X cardinal 20 X wine 34 red (X indicating a blend) to chrome yellow 10 (600 ppm), apricot 11 (300 ppm) and copper brown 14 (150 ppm). The yellow disk florets or "eye" of 'Lucindo' and 'Regal Davis' daisy flowers did not appear to be noticeably affected by Primo. Ray florets of 'Red Delano' were changed by Primo from a wine 34 X cardinal 28 red to orange 18 X copper 9 (600 ppm), rust 21 X blood 27 red (300 ppm), to blood 27 X cardinal 28 red (150 ppm). 'Redding's' maroon 42 ray florets became burnt orange 12 (600 ppm), cinnamon 13 (300 ppm) and brick 20 X rust 21 red (150 ppm) with Primo treatment. The purple 39 ray florets of 'Regal Davis' became blush pink 36 X ivory 8 (600 ppm), blush pink 36 (300 ppm) and rose pink 37 (150 ppm) following Primo treatment. B-Nine did not appear to affect ray floret color.

Primo did not affect the number of flowers per plant or plant quality of any cultivar (data not shown). 'Lucindo' plants did not show differences in any growth parameter with treatments (Table 1). 'Lucindo' plant height and flowers per plant (P = .08) were close to being significant. Plant height of 'Red Delano', 'Redding' and 'Regal Davis' plants was retarded by Primo sprays with the retardation increasing with rate (linear response). 'Regal Davis' plants showed a quadratic response with Primo treatment. All spray rates of Primo retarded the height of 'Red Delano' and 'Redding' plants as well as 5,000 ppm B-Nine. Primo differed with B-Nine in retarding the height of 'Regal Davis' plants with 600 ppm Primo producing the shortest plants. Plant canopy areas of B-Nine- and Primo-treated plants of all cultivars except 'Lucindo' were similar and produced shorter plants than untreated plants. Shorter plants were produced with increasing Primo rates (linear response). Flowering date was increased in 'Red Delano' and 'Regal Davis' plants sprayed with Primo. The delay in flowering was linear, increasing with Primo rate. With the exception of 'Regal Davis' plants, plants treated with B-Nine and Primo had similar flowering dates.

Significance to Industry: Primo is an effective new growth retardant that produces retardation in chrysanthemum equal to B-Nine. When applied to red-purple cultivars, Primo interferes with pigment synthesis yielding new colors and retarding stem elongation with no other undesirable growth effects. Primo ushers in a whole new era of chemical control of flowering in plants. New colors were consistent with rate, therefore the useful marketability of a red/ purple cultivar with outstanding growth habits and flower form and number can be expanded by using Primo as a growth retardant. Primo may be a more effective retardant than B-Nine under high temperature growing conditions and this aspect of Primo merits further study.

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Table 1. Plant height, canopy area and flowering date of 4 chrysanthemum cultivars sprayed with daminozide and cimectacarb.

	Growth parameter			
Treatment spray (ppm)	Lucindo	Red Delano	Redding	Regal Davis
	Plant height (cm)[Z]			
No treatment	36	33	39	32
5,000 B-Nine	—	27	26	26
600 Primo	29	26	26	21
300 Primo	28	27	27	23
150 Primo	33	30	29	26
	Significant contrasts			
Daminozide vs 3 Primo rates	ns	ns	ns	xx
Linear	ns	xx	xx	xx
Quadratic	ns	ns	ns	xx
	Plant canopy area (cm^2)[Y]			
No treatment	2379	2384	2592	1804
5,000 ppm B-Nine	——	1673	2105	1901
600 Primo	2117	1570	1911	1696
300 Primo	2310	2092	2330	1697
150 Primo	2366	1972	2089	1872
	Significant contrasts			
Daminozide vs 3Primo rates	ns	ns	ns	ns
Linear	ns	xx	xx	ns
	Flowering date (davs)[X]			
None	73	74	81	70
5,000 B-Nine	—	71	81	71
600 Primo	73	79	77	76
300 Primo	73	77	81	72
150 Primo	73	77	81	72
	Significant contrasts			
Daminozide vs 3 Primo rates	ns	ns	ns	xx
Linear	ns	xx	ns	xx

[Z]Metric conversion: 2.5 cm = 1 inch.
[Y]Diameter measured in two directions at top of the plant and multiplied together.
[X]Flowering date measured from planting date. All cvs. except 'Redding' (9 weeks) 8-week cvs. Plants received 14 days vegetative lighting.

Uniconazole Alters Stem Anatomy of 'Spectabilis' Forsythia

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Nature of Work: Plant growth regulators such as uniconazole have the potential to reduce vegetative growth and frequency of pruning for woody landscape species. Previous work has established that uniconazole can effectively retard growth of several woody landscape species without injury (6). Little information is available however, on the effects of uniconazole on woody plant morphology or anatomy. Therefore, the objective of this research was to investigate anatomical changes in secondary stem development of *Forsythia x intermedia* 'Spectabilis' by evaluating stem tissues initiated following a foliar (leaves and stems) application of uniconazole.

Materials and Methods: Rooted stem cuttings of 'Spectabilis' forsythia were potted into 3.8 liter (#1) containers with arcillite, a calcined clay substrate. Uniconazole was applied as a foliar spray at five rates: 0, 90, 130, 170 or 210 ppm; 0 ppm was maintained as a nonpruned control. The experimental design was a split plot with four replicates assigned to blocks based on initial plant size. Uniconazole rates were randomly allocated to main plots and five harvest dates [0, 40, 80, 120, and 369 days after treatment (DAT)] were randomly allocated to subplots within each main plot. Plants were maintained under drip irrigation applied twice daily at 500 ml (16.9 oz) per container per application. Plants were fertilized twice weekly with 500 ml (16.9 oz) of a nutrient solution containing 200 ppm N from a 20N-4.3P-16.6K water soluble fertilizer (Peters 20-10-20 Peat Lite Special). The solution also contained 15 ppm Ca provided by CaSO4. Data herein only represent results from tissues collected 120 DAT.

Histological procedures. Stem tissue samples were collected from the first visible internode to elongate after uniconazole application. Tissue samples were fixed by vacuum infiltration with FAA, dehydrated and infiltrated in a series of ethanol and tertiary butyl alcohol (2), and embedded in TissuePrep using a Model 166 Histomatic Tissue Processor. Tissue samples were sectioned serially on a rotary microtome at l0 μm thickness, affixed to slides using Haupts adhesive (1), and stained with safranin and fast green (2).

Statistical analyses. Cortical parenchyma, phloem fiber, phloem cell and xylem cell quantities, and epidermal cell width were determined from cross sections. Xylem vessel and ray parenchyma length and width, and epidermal cell width and depth were measured from radial sections. Data were subjected to analysis of variance procedures (4) to determine sources of experimental variation and differences among treatments were determined significant at $P< 0.5$. Uniconazole concentration response (0 ppm excluded) was analyzed by general linear regression. A planned orthogonal contrast to test for a difference between a pooled uniconazole treatment effect and nontreated control (0 ppm) was also conducted.

Results and Discussion: Microscopic examination of cross-sections of stems indicated uniconazole application influenced stem tissue development. Stems from nontreated plants were composed of 10 to 12 bands of cortical parenchyma cells, few bundles of phloem fibers, 11 to 13 bands of phloem cells, and 63 ±9 bands of xylem cells surrounding the chambered pith region. The chambered pith of 'Spectabilis' forsythia consisted of sparse and dense regions of parenchyma cells which were not affected by uniconazole application.

The number of bands of cortical parenchyma from nontreated and uniconazole-treated plants did not differ. Forsythia treated with < 210 ppm uniconazole contained a greater number of phloem fibers that were smaller in diameter than those from stem tissues of nontreated plants (data not presented). Lumen of phloem fibers from uniconazole-treated plants appeared larger than lumen of phloem fibers of nontreated plants. Wang and Gregg (5) reported uniconazole decreased the number and size of phloem fibers while lumen size for phloem fibers increased for 'Jane Cowell' hibiscus *(Hibiscus rosa-sinensis* L. 'Jane Cowell'). However, uniconazole resulted in only limited fiber wall thickening within stems of 'Annette Hegg Dark Red' poinsettia *(Euphorbia pulcherrima* Willd. 'Annette Hegg Dark Red') that were described as having very few thickened phloem fiber cells in bundle caps (3).

While phloem tissue width varied within each stem sample, the number of bands of cells ranged from 11 to 13 regardless of uniconazole concentration. This similar number of phloem cells indicates phloem cell initiation was not affected while cell expansion was suppressed.

Xylem tissues from stems of plants receiving uniconazole contained 22 ±3 to 28 ±5 bands of xylem cells while xylem tissue from stems of control plants contained 63 ±9 bands of xylem cells. This represented a 65% decrease in the number of bands of xylem cells initiated for uniconazole treated plants. Suppression of stem xylem tissues was similar for all plants receiving uniconazole; a response consistent with internode diameter measurements of 2.6 mm (0.102 in.) for nontreated plants and 2.2 mm (0.087 in.) for uniconazole treated plants. Individual xylem vessels of uniconazole treated plants appeared smaller in diameter as viewed in cross sections and this was confirmed by measurement of xylem vessels viewed in radial sections (Table 1). Similar uniconazole induced suppression of xylem initiation was reported for 'Jane Cowell' hibiscus (5) and 'Annette Hegg Dark Red' poinsettia (3). Xylem ray expansion, evaluated from radial sections, was also suppressed with uniconazole application (Table 1).

While initiation and expansion of secondary xylem was suppressed by uniconazole application, initiation of secondary phloem was not affected. This pattern of development for uniconazole treated plants resulted in a greater proportion of phloem tissue per xylem tissue than was present in nontreated plants.

It is not known if epidermal cell numbers were altered by uniconazole application; however, expansion of epidermal cells was affected by uniconazole application resulting in a change in epidermal cell shape. While the outermost layer of epidermal cells were square to rectangular when viewed in cross-section, these same cells for uniconazole-

treated plants were very narrow and elongated when viewed in radial sections (Table 1).

Significance to Industry: Data indicate uniconazole has an effect on the basic structure of secondary stem tissues of forsythia. This alteration of stem structure did not appear to have a negative effect on subsequent growth of the plants harvested 365 DAT. Since these stem tissues would provide the basic framework for all subsequent growth of the plants, this response should be investigated further to determine if the altered stem anatomy will persist or if these plants will exhibit poor structural stability as they continue to grow.

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Table 1. Effect of uniconazole on mean size (μ) of cells within stems of 'Spectabilis' forsythia 120 days after treatment.

	Uniconazole concn. (ppm)					Significance[z]		
Cell type	0	90	130	170	210	L	Q	Uvs.0
Xylem vessel								
Length	38.62	17.81	21.00	17.31	14.25	0.003	0.002	0.001
Width	2.34	2.19	1.84	2.15	2.01	NS	NS	0.0
Ray parenchyma								
Length	4.65	4.41	4.53	3.97	3.47	0.003	NS	NS
Width	2.59	2.44	1.96	2.31	2.06	NS	NS	0.01
Epidermal cell								
Depth (radial sections)	3.81	4.56	4.56	5.06	4.41	NS	NS	0.001
Width (radial sections)	3.80	1.61	1.76	1.68	1.44	0.002	0.001	0.001
Width (cross sections)	4.17	2.45	2.46	2.03	2.72	0.001	0.001	0.001

[z] L, Q, and Uvs.0 = Linear, Quadratic regression, and Uniconazole (mean of 90, 130, 170, and 210 ppm) vs. 0 ppm orthogonal contrast, respectively. NS = P> 0.05.

Climate Alters the Effect of Paclobutrazol on Leaf Morphology of Landscape Plants

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Nature of Work: Climatic differences can have a considerable impact on plant phenotype. Earlier research has shown that morphological adaptations of leaves to low humidity, high light environments include increases in leaf shape and thickness (3). Paclobutrazol retards plant growth by inhibition of gibberellin biosynthesis (1, 2, 4, 5). The efficacy of paclobutrazol might be regulated by environmental factors associated with differences in climate. For ornamental plants, our understanding of the interactive affects of paclobutrazol with the environment on leaf morphology is critical because of potential affects on plant aesthetics and subsequent market value. Our objective was to study the interaction of dissimilar climate with paclobutrazol on leaf morphology of two landscape shrubs. A research experiment was replicated using similar procedures and cultural practices at the Arizona State University Horticultural Resource Center in Tempe, AZ, (33.5°N 112°W) and the University of Georgia Coastal Plain Experiment Station in Tifton, GA (32°N 83°W). Same-source, uniform-rooted liners of *Acca Sellowiana* (pineapple guava) and *Ligustrum japonicum* (Japanese privet) were transplanted into l-gal. black polyethylene containers March 2, 1992. The rooting medium consisted of a 3 milled pine bark, 1 peat moss and 1 sand (by vol.). Plants were watered daily to container capacity at the rate of 0.6 inch H_2O per watering using overhead irrigation at both locations so as to not allow development of plant water stress. Paclobutrazol sprays of 0 (deionized water control) or 750 ppm were applied uniformly to the shoots of all plants at both locations on March 25, 1992. Five months after application, plants were harvested for analysis of leaf morphology. All measurements and observations were made on only the most recently fully-expanded leaves which had developed fully under their respective production regimens. Leaf area was measured using an image analysis system (DIAS Decagon Devices Inc., Pullman, Wash.). Leaves were then oven dried at 149°F for 48 hr and weighed. The experiment was a 2 location x 2 paclobutrazol factorial arranged in a randomized complete block design with 4 replications.

Results and Discussion: During the summer of 1992, mean daily maximum and minimum temperatures at the Arizona location were 13 to 15°F and 3 to 10°F higher, respectively, than at the Georgia location. Untreated leaves of both species were generally smaller and thicker when grown in Arizona than when grown in Georgia. Leaf area of both species and leaf thickness of pineapple guava were affected by an interaction of climate with paclobutrazol. Compared with control plant leaves, paclobutrazol 1) increased pineapple guava leaf area by about 45 % in Georgia but not in Arizona, 2) decreased Japanese privet leaf area in both Arizona and Georgia by about 50%, and 3) decreased pineapple guava and Japanese privet leaf thickness in Arizona by 25% and 19%, respectively, but not in Georgia.

Significance to the Nursery: Compared with leaves from the humid, temperate Georgia location, leaves from the drier, hotter Arizona climate with more intense solar radiation tended to be smaller and thicker. Paclobutrazol reduced leaf size of Japanese privet at both locations; however, paclobutrazol's effect on leaf area of pineapple guava was limited to the Georgia location. Our data demonstrate that universal application rate recommendations for paclobutrazol may not be appropriate for all landscape plants.

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