Growth Regulators

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Section Editor

Responses of Knock Out® Roses to Topflor® G Applied at Liner Transplant

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Significance to Industry: Knock Out® rose is a popular shrub rose and a major container crop in the southeastern United States. Growers are interested in using plant growth regulators to reduce pruning needs, improve plant quality, or manage crop scheduling. In this study, Topflor G® applied at two weeks after liner transplant at 14 or 21 g per 3-gal container effectively controlled plant size for 'Double Knock Out®' and 'Pink Double' Knock Out® roses. Plants treated with 21 g reduced pruning needs, and plants treated with 14 g had fewer clippings. However, plant quality considering size, growth habit, shape, and flowering, was greater in untreated-pruned plants (grower treatment) than treated plants, and variations in plant quality within individual PGR treatments were big. Based on these preliminary results, further studies on application timing and technique are needed to develop recommendations for using Topflor G® during production of Knock Out® roses.

Nature of Work: Knock Out® roses are a major nursery crop in southeastern United States. Usually several crops are scheduled to grow throughout fall and winter, targeting a wide market window from spring to early summer of subsequent year, with some selling being in fall. Although length of a production cycle varies from 6 to 10 months depending on the season of growth, at least three sheerings are needed during production to balance plant shape and improve branching. A marketable plant (as defined by a local grower) needs to be "full and balanced", specifically, should have a 1) marketable size with container surface completely covered by plant canopy, 2) canopy is round-shaped without skewing to one side, and 3) abundant flower buds are visible, with 5% to 10% showing color or in bloom.

Topflor G® is a granular formulation of the plant growth regulator Topflor® (flurprimidol), and is registered on herbaceous and woody ornamental plants in container production. Flurprimidol reduces internode elongation through inhibiting GA3 biosynthesis, and has been reported to control growth of a wide range of plant species including bedding plants and floricultural crops (2 and 3). Additional potential benefits to ornamental plants include improved foliage color, flowering, or drought tolerance of some plant species (1). However, effects of Topflor G® on Knock Out® roses or similar rose crops have not been evaluated.

The experiment was conducted at a local nursery in Amite, Louisiana (US Department of Agriculture Plant Hardiness Zone 8b). Four groups of rose liner plants: 'Knock Out®' (red single flowers), 'Pink Double Knock Out®', 'Double Knock Out®' (red double flowers), all in quart-size pots, and 'Double Knock Out®' in 4-in-size were transplanted into 3-gal pots on 20 June 2012. Estimated target market dates were Feb. to Mar. 2013 for quart-size transplants, and June 2013 for 4-in transplants. Each group was treated with Topflor G® at 0, 7, 14, or 21 g per pot at four weeks after transplant. Topflor G® was hand-broadcast to media surface using a teaspoon. Treated plants were arranged as a randomized complete block design with 8 replications, and placed in the block of the same cultivar at the nursery. Plants were grown under grower's irrigation and fertilization practices, and followed grower's shearing schedule for individual cultivars. Plant height and width (average of widest width and the perpendicular width to the widest width) were recorded at 0 (initial), 2, 5, 23 (mid-stage), and 34 (marketable stage, 47 for 'Double Red' from 4-in liner) weeks after treatment (WAT). Plant visual quality was rated at mid- and marketable stages using scale ranged from 1 to 10, considering plant size, fullness, shape, leaf color, and flower abundance, with 1 = dead plant, 2 to 3 = poor quality, 4 to 5 = below average, 6 to 7 = average, 8 to 9 = good, and 10 = premium quality with desirable size, plant canopy covered pot surface, a balanced shape, dark green mature leaves, with flowers and buds (ideally with 5 to 10% flower buds showing color). At marketable stage, leaf relative chlorophyll content was measured by a SPAD meter, and presented as SPAD meter readings. Number of open flowers and flower buds were also quantified (except the original 'Knock Out'). Flowers were considered open when the outer petals were reflexed to reveal the inner petals or carpels. 'Total flower count' was the addition of spent and open flowers and buds. ANOVA was conducted and means were separated by Fisher's Protected LSD. Regression analysis was performed to identify rate responses among cultivars.

Results and Discussion: 'Double Knock Out' from quart liner had the most vigorous growth. Plants were pruned at 7 and 22 WAT. Plant height was not affected by TopflorG at mid-stage. Plant width was not affected by PGR treatments until 8 WAT, where plants treated with 14 g/pot were 11% smaller in diameter than untreated plants (data not shown). At marketable stage (34 WAT), 14 and 21 g/pot reduced 18% and 28% in plant height compared to untreated plants, respectively, and width was 15% and 21% smaller than untreated plants, respectively (Fig 1). Plant shape, as indicated by height:width ratio, was more spreading (lower ratio) in plants treated with 7 g/pot than untreated. This trend was observed with higher rates, but not as significant as the low rate. Number of flowers and flower buds were not affected. However, total flower counts were marginally affected, and high rate reduced total flower counts (total of spent and open flowers and buds, 30 vs. 36). Plants treated with 14 and 21 g/pot had darker green foliage (higher SPAD) than untreated (50.5 and 48.8, vs. 45.5, respectively). Overall visual quality of those treated at the low rate was similar as untreated plants. However, those treated at higher rates were rated lower quality, possibly can be attributed to smaller plant sizes and lower branches hanging out of the sides of pots. These hanging branches were caused by growth habit changing from upright to more spreading, and may prone to breakage during shipping.

Plants of 'Double Knock Out' from 4-inch liner were pruned at 22 WAT. From 5 WAT to marketable stage (47 WAT), plant height was reduced 20% and 35% by 14 or 21g/pot PGR compared to untreated. Width was not affected by PGR treatments throughout the production period. Similar results were observed in plant shape (height:width ratio) as Double Knock Out from quarts. At 47 WAT, plants were at early stage of blooming, and number of flowers were fewer in treated plants (2 at 21 g/pot, 8 at 14 g/pot) than untreated (flower = 11), although total flower counts were similar among treatments. Overall plant quality was similar among untreated and PGR treatments at 7 and 14 g/pot. The high rate, 21 g/pot reduced quality compared to untreated and the low rate.

Plants of 'Pink Double Knock Out' from quart liner were pruned at 22 WAT. Plant height and width were affected by TopflorG since 5 WAT and throughout the production period. At marketable stage (34 WAT), heights of plants treated with 7, 14 and 21 g/pot were 25%, 34%, and 38% shorter than untreated, respectively (Fig 1, Photo 1). Plant width was 7%, 17%, and 21% smaller than untreated. Similar to other cultivars, shape of treated plants was more spreading than upright compared to untreated. Darker green foliage (higher SPAD) was observed in plants treated with 14 and 21 g/pot compared to untreated (48.4 and 47.8, va. 43). Number of flower buds were fewer in those treated with 14 and 21 g/pot (29 and 28, vs. 39), and flower counts were lower in these plants too (38 and 38.3, vs. 51). Overall plant quality of 14 and 21 g/pot was lower compared to untreated and the 7 g/pot, possibly due to smaller size (Photo 2), hanging branches (Photo 2), and fewer flowers.

Plants of 'Knock Out' from quart liners grew the least vigorously among tested cultivars. Plants were pruned at ~14 WAT. Plant width, but not height, was affected by PGR treatments at 8 WAT. At mid-stage (23 WAT), plants treated with 21 g/pot were 17% shorter and 10% smaller in diameter than untreated, and no difference was found among other treatments. At marketable stage (44 WAT), except plants treated with the high rate, all treatments were similar in plant height and width. Number of flowers, buds, and flower power were reduced by the high rate compared to untreated and low rate, 7g/pot. Overall plant quality was lower for plants treated at the high rate.

Summary: TopflorG reduced plant growth and the effect was rate and cultivar dependent. Vigorous cultivars responded more than slow-growing cultivars. Plants having bigger root balls (quart liner) at the time of treatment responded more than those having smaller root balls (4-in liner). Growth reductions were caused by shortened internodes. Numbers of leaves were not affected by application of TopflorG (data not shown). Plants may be able to skip one pruning at the high rate, but at least one pruning was needed before finishing to have new foliage and abundant flower buds. Because TopflorG reduced plant size, treated plants will need additional time to finish and thus a longer production time. If treated plants were pruned later and lighter than untreated, they may be able to finish at the same as other plants. Plant growth was in a way that lower branches became more spreading (even hanging) instead of upright growth. This is considered by this grower as undesirable. Another shape-related issue observed was skewing of canopy to one side in some plants. This can be corrected by

hand pruning for untreated plants, but was harder to correct in treated plants because less growth on the side that was originally weak. The leaf color was darker in plants treated with higher rates, which has been noticed on other ornamentals. However, this effect did not significantly improve overall plant quality. Number of flowers or flower power may be negatively affected, especially at the high rate. Due to these changed in treated plants, especially at high rate, visual quality was negatively affected by TopflorG application.

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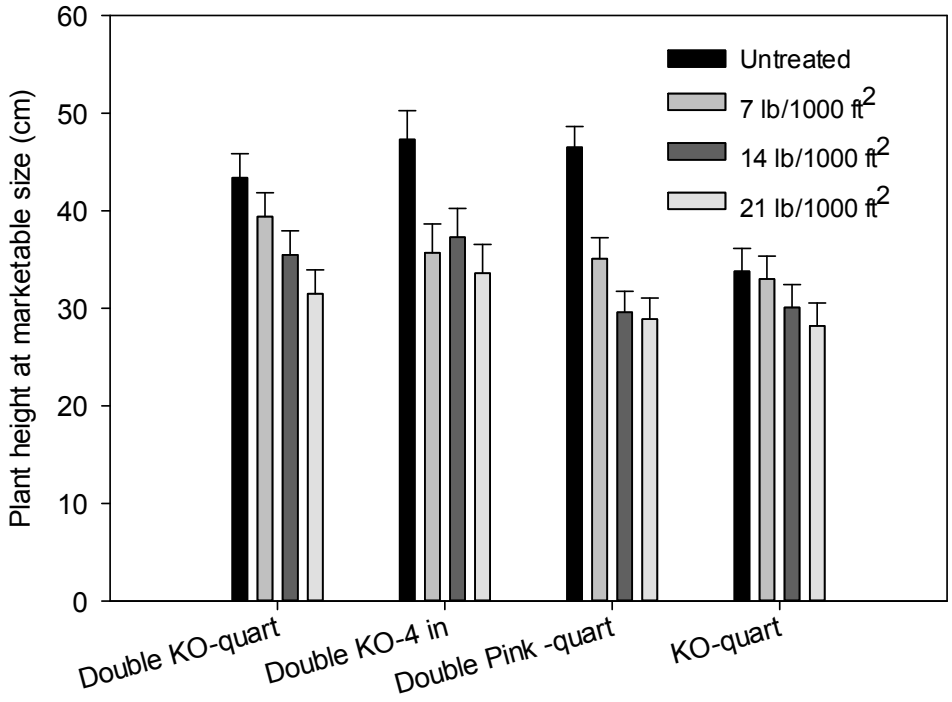

Fig. 1. Plant height at marketable stage for "Double Knock Out" from quart (34 WAT) and 4-inch liners (47 WAT), 'Double Pink" from quart liner (34 WAT) and at mid-stage of "Knock Out" from quart liner (23 WAT).

Photo 1. ‘Pink Double Knock Out’ treated with TopflorG at (from left) 0, 7, 14, and 21 g/pot at 34 WAT.

Photo 2. Left: hanging branches observed in ‘Pink Double Knock Out’ treated with TopflorG at low rate (plant on the right); right: skewing observed in ‘Pink Double Knock Out’ at high rate (plant at right). Both were at marketable stage (34 WAT).

Effects of Plant Growth Regulators and Propagation Technique on *Clethra alnifolia* 'Hummingbird' and *Rhododendron* 'Roseum Elegans'

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Index Words: dikegulac sodium, benzyladenine, BA, *in vitro*, PGR, plant quality, flurprimidol

Significance to Industry: Consumers prefer container plants that are dense and symmetrical. Plants that are compact are easier to transport, save space during production, transportation, and display, and do not blow over as easily as less compact plants. The purpose of this study was to evaluate the effects of propagation technique and plant growth regulators (PGRs) Augeo®, Configure®, and Topflor® on branching and visual quality of *Clethra alnifolia* 'Hummingbird' and *Rhododendron* 'Roseum Elegans'. For clethra, plants grown from *in vitro*-propagated liners had more branches and were of higher quality than those from cutting-propagated liners. For rhododendron, plants grown from *in vitro*-propagated liners and pruned prior to treatment had more branches, were smaller in size, and had greater visual quality than those grown from cutting-propagated liners. Pruning produced more branches than water control and PGR treatments. None of the treatments resulted in higher quality than the water control. Based on this study, in vitro-propagated clethra and rhododendron from in vitro-propagated liners plus one pruning appear to be the most promising treatments.

Nature of Work: Consumers of nursery products desire plants that are full and cover the surface of the container in which they are sold (6). Growers and retailers prefer plants that are well branched and compact (12) to reduce space required per crop and minimize toppling due to wind. To produce the plants that satisfy the desires of both retail and wholesale customers, growers often modify growth with pruning. Pruning induces branching by removing apical buds, causing lateral buds to break (17). Pruning is generally labor intensive, especially in nurseries producing a wide selection of ornamental species (11) and, therefore, can be very expensive for growers (8). While pruning is a very common practice, it does not always increase branching (3, 7, 13).

PGRs can be an alternative to pruning to increase branching and improve plant quality while lowering labor costs. Foliar application of benzyladenine (BA) to *Ilex crenata* increased the number of branches (19). Augeo (dikegulac sodium), a chemical pincher, applied to Little Lime™ hydrangea increased branching and branching symmetry without reducing panicle number (3). Dikegulac sodium applied to euonymus (*Euonymus fortunei*), crape myrtle (*Lagerstoemia*), and honeysuckle (*Lonicera*) increased branch number and decreased branch elongation, resulting in a more

compact plant (2,9). Mefluidide increases lateral branching in peach (1) and Chinese hibiscus (18). Uniconazole, a GA-3 biosynthesis inhibitor, decreased growth when applied to flame and 'Sunglow' azalea, forsythia, 'Compacta' and 'Nellie R. Stevens' hollies, and mountain pieris resulting in more compact plants (16).

Several plant species have been observed developing more branches when propagated *in vitro*. *In vitro* propagation resulted in increased branching of strawberry, grape and blackberry when compared with the parent plants (4, 10, 14, 15). *In vitro*-propagated blueberries had significantly higher yields for the first three years than their cutting-propagated counterparts. These higher yields were directly related to the increased branching of the *in vitro*-propagated plants (5). Growers have reported more branches among *in vitro*-propagated red maple liners when compared to cutting propagated liners. Several other plants have been observed to have similar results including rhododendron and magnolia (E. Kinsey, personal communication). However, there are no published reports on the effect of propagation technique on branching of ornamental plants or on differential efficacy of PGRs based on propagation technique. Therefore, the objectives of this study were to explore the effectiveness of PGRs [Configure (BA), Augeo (dikugulac-sodium), and Topflor (flurprimidol)] and propagation technique (cutting and tissue culture) on enhancing branch architecture and plant quality for *Clethra alnifolia* 'Hummingbird' and *Rhododendron* 'Roseum Elegans'.

Clethra alnifolia 'Hummingbird' plants purchased as *in vitro*-propagated (2 ¼-inch, Briggs Nursery, Elma, WA) or cutting-propagated liners (2 ¼-inch, Spring Meadow Nursery, Grand Haven, MI) were potted into 1 gal containers with 85% pine bark and 15% peat on 27 April 2012. Plants were placed outside under 50% shade to acclimate. After 4 days, plants were moved to 25% shade. Two weeks after potting, plants were placed in full sun in the nursery compound at the University of Tennessee in Knoxville, TN (USDA Plant Hardiness Zone 7a).

Rhododendron 'Roseum Elegans' *in vitro*-propagated liners (2 ¼-inch, Briggs Nursery) and rooted cuttings (2 ½ inch, Avery County Extension Office, NC) were potted as described above on 25 May 2012, and kept in 25% shade for the remainder of the experiment. Two weeks after potting, all plants were top dressed with a 19N–1.7P–6.6K, 5- to 6-month controlled release fertilizer with minors (Harrell's, Lakeland, FL) at 14 g per container (medium-high label rate). Plants were hand-weeded as needed and watered by overhead automatic irrigation twice daily.

Initial growth index [(height +width 1+width 2)/3] and branch number were recorded 14 June 2012. Clethra and rhododendron were separated into treatment groups and either Augeo, Configure, or Topflor at 800, 600, 150 ppm, respectively, were foliar applied on 21 June 2012. Plants were sprayed until the foliage was thoroughly wetted. Two control treatments, a hand pruned and a water spray, were also applied. For clethra, the hand-pruning treatment consisted of pruning each stem to a lateral bud 6" from soil surface, and for rhododendron, apical buds were manually removed with pruners.

Cutting and *in vitro*-propagated clethra liners were pruned several times during liner production, but neither were pruned prior to shipping to us. The *in vitro*-propagated rhododendron liners were mistakenly sheared just prior to shipping; liners from cuttings were not pruned and were mostly apical cuttings. In order to account for this disparate treatment prior to the experiment, our objective with rhododendron shifted to comparing *in vitro* propagation plus one pruning with cutting propagation. For simplicity within the text and tables, *in vitro*-propagated rhododendron refers to *in vitro*-propagated rhododendron plus one pruning. As a result of different plant growth stages between the two groups of liners, they were treated with PGRs based on phenological stage rather than weeks after potting. Specifically, each group was treated when plants finished a flush and set apical buds. *In vitro*-propagated plants flushed and set buds before the cutting propagated plants, and as a result, rhododendron produced by *in vitro* were sprayed two weeks before the cutting-propagated plants (5 July 2012).

Phytotoxicity symptoms were rated two weeks after treatment (WAT) on a 0 to 10 visual scale, where 0 represented no injury, and 10 represented complete kill. Branch number and growth measurements were recorded at 4, 8, and 12 WAT. Quality was determined at 12 WAT on a 1 to 5 scale. For clethra, a rating of 1 represented sparsely branched and asymmetrical plants with an open canopy, 2 represented sparsely branched and asymmetrical plants with a closed canopy, 3 represented more densely branched and asymmetrical plants with a closed canopy, 4 represented densely branched, symmetrical plants, 5 represented densely branched and symmetrical plants that completely covered the pot surface. In rhododendron, a rating of 1 represented plants that had one strong stem, branch development on distal portion of stem only, causing minimal coverage of the pot surface, 2 represented two or more stems with a narrow, columnar growth pattern, branch development occurring distally, 3 represented two or more stems with branch development occurring at the base, covering at least 70% of the container surface when viewed from above, 4 represented multiple stems that cover approximately 90% of the container surface, 5 represented multiple stems from base and covered 100% of the container surface.

Experiments were conducted using a completely randomized design in a factorial arrangement with repeated measures. There were 10 single plant replications for each treatment. Data were analyzed using the GLM procedure of SAS (9.3S; SAS Institute, Cary, NC). Means were separated using Tukey's HSD, $\alpha = 0.05$. Each plant species was analyzed as a separate experiment.

Results and Discussion: For clethra, there was no interaction between the two factors for branch number, but for GI, there was an interaction at 8 WAT where cutting-propagated clethra were smaller, except when treated with Augeo or Configure (Table 1). Clethra plants propagated *in vitro* had 18.3 (71%) more branches than cutting-propagated plants at the initiation of the experiment (Table 2). In addition, *in vitro* plants had 31.0, 39.5, and 45.8 more branches at 4, 8 and 12 WAT, respectively, compared with cutting-propagated plants, almost double the amount of branches at each sample date (83%, 70%, and 71%). They were also visually more ramose, as illustrated by the

quality rating (3.9 vs. 2.5) (Tables 2 and 3). Clethra treated with Topflor and pruning had significantly fewer branches than the water control at 4, 8 and 12 WAT. Branch number for plants treated with water, Augeo, and Configure were not different at any data collection period. At all three data collection periods following the PGR applications, pruning yielded fewer branches than water controls by an average of 32%.

Clethra propagated by cuttings initially had a 6% lower GI than *in vitro* plants, and maintained a 6% lower GI throughout the experiment except for at 8 WAT (Tables 1 and 2). Clethra treated with Augeo, Topflor, and pruning had a 9%, 13%, and 17%, respectively, lower GI than the water control at 4 WAT. Topflor and pruning-treated clethra continued to have a lower GI than the water control by 15% at 12 WAT, and plants treated with Topflor were more compact than those pruned by an average of 15%.

There was no difference between cutting and *in vitro*-propagated clethra phytotoxicity symptoms (Table 3). Augeo and Topflor had higher phytotoxicity ratings than water control but were generally not a long-term problem. *In vitro*-propagated clethra received a higher quality rating than cutting-propagated clethra (3.9 vs. 2.5) (Table 3). Topflor-treated clethra had a higher quality rating then the water control and Augeo. No other treatments were different from the water control.

There was an interaction between PGR and propagation method at 4 WAT for rhododendron. The *in vitro*-propagated plants had more branches than cutting-propagated plants except for cutting-propagated plants that were pruned (Table 4). Rhododendron propagated *in vitro* had 2.15 (111%) more branches than cutting-propagated plants at the initiation of the experiment and continued to have more branches throughout the experiment with an exception at 4 WAT (Table 5). For example, *in vitro* plants at 8 and 12 WAT had, respectively, 1.94 (72%), and 2.25 (73%) more branches compared with cutting-propagated rhododendron. Unlike clethra, no treatment was effective at inducing branching until 8 WAT for rhododendron. Pruned control at 8 and 12 WAT had an average of 32% more branches than the water control, but no PGRs were effective at increasing the branch number of rhododendron.

Rhododendron propagated *in vitro* initially had a 9% lower GI than cutting propagated plants and maintained a lower GI at 4, 8 and 12 WAT by 17%, 15% and 7%, respectively (Table 5). Rhododendron treated with Augeo, Topflor and pruning had a 13%, 22%, and 22%, respectively, lower GI than the water control at 4 WAT and a 10%, 27%, and 21%, respectively, lower GI at 8 WAT. Topflor and pruning-treated rhododendron maintained a lower GI than the water control by 20% and 14%, respectively, at 12 WAT.

There was an interaction between PGR and propagation technique for phytotoxicity. No treatment was more phytotoxic than the water control except cutting-propagated Configure-treated plants, which had thinner leaves that were lighter in color (Table 6). Rhododendron propagated *in vitro* had a higher quality rating than cutting-propagated

rhododendron (2.9 vs. 2.5) at 12 WAT (Table 7). For rhododendron, no PGR led to higher quality than the water control, but Topflor-treated plants had higher quality than Augeo and pruned plants.

Compact, well-branched plants are desirable to growers and consumers. *In vitro* clethra and rhododendron (in vitro + one pruning) were more well-branched and had higher quality than cutting-propagated plants in our studies. For both species, PGRs were not more effective at increasing branch number than one or both control treatments (water spray or pruning).

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Table 1: Interaction of propagation method and PGRs on growth index of *Clethra alnifolia* 'Hummingbird' at 8 WAT.

PGR treatment	Growth index (cm)	
	Cutting	*In vitro*
Water	46.1 ab[z]	46.6 a
Augeo	44.5 ab	43.6 abc
Configure	45.1 ab	44.0 abc
Topflor	31.7 d	38.0 cd
Pruned	39.7 bc	42.2 abc
Significance		*

[z]Means within a column followed by the same letter were not significantly different (Tukey's HSD α = 0.05).

Table 2: Number of branches and growth index (GI) of *in vitro*- and cutting-propagated *Clethra alnifolia* 'Hummingbird' at 0, 4, 8, and 12 weeks after PGR treatments.

Treatment	Initial (0)		4 WAT		8 WAT		12 WAT	
	Branch (no.)	GI (cm)	Branch (no.)	GI (cm)	Branch (no.)	GI (cm)	Branch (no.)	GI (cm)
Propagation								
Cutting	25.6 b [z]	25.4 ba	37.2 b	32.9 b	56.2 b	-[y]	64.6 b	44.0 b
in vitro	43.9 a	26.9 a	68.2 a	36.0 a	96.7 a	-	110.4 a	45.8 a
Significance	***	*	***	***	***	-	***	***
PGR treatment								
Water	—[x]	—	61.8 a	37.6 a	89.0 a	-	99.6 a	49.1 a
Augeo	—	—	62.5 a	34.3 bc	82.7 a	-	94.2 ab	46.7 ab
Configure	—	—	61.1 a	36.4 ab	88.6 a	-	96.2 ab	47.8 a
Topflor	—	—	41.8 b	32.6 c	62.3 b	-	70.5 c	37.1 c
Prune	—	—	37.2 b	31.3 c	57.2 b	-	77.2 bc	43.7 b
Significance	—	—	***	***	***	-	***	***

[z]Means within a column followed by the same letter were not significantly different (Tukey's HSD α = 0.05).

[y]Dashes indicate interaction between propagation method and PGR applied.

[x]Analysis not conducted because treatments had not been applied on this date.

Table 3. Phytotoxicity at 2 weeks after treatment (WAT), and plant visual quality at 12 WAT of in vitro- or cutting-propagated *Clethra alnifolia* 'Hummingbird' in response to PGR treatments.

Treatment	Phytotoxicity	Quality
Propagation		
Cutting	0.9	2.5 b
in vitro	0.9	3.9 a
Significance	NS	***
PGR treatment		
Water	0.1 c[z]	3.0 b
Augeo	2.5 a	3.0 b
Configure	0.4 c	3.1 ab
Topflor	1.5 b	3.7 a
Prune	0.1 c	3.2 ab
Significance	***	*

[z]Means within a column followed by the same letter were not significantly different (Tukey's HSD α = 0.05).

Table 4: Interaction of propagation method and PGRs on branch number of *Rhododendron* 'Roseum Elegans' at 4 WAT.

	Branch number	
PGR treatment	Cutting	in vitro
Water	2.4 cd[z]	4.3 a
Augeo	2.5 bcd	4.1 ab
Configure	1.9 d	4.1 ab
Topflor	2.0 d	4.3 a
Pruned	4.0 abc	3.8 abc
Significance	**	

[z]Means within a table followed by the same letter were not significantly different (Tukey's HSD α = 0.05).

Table 5. Number of branches and growth index (GI) in *in vitro*- and cutting-propagated *Rhododendron* 'Roseum Elegans' at 0, 4, 8, and 12 weeks after PGR treatments (WAT).

Treatment	Initial (0)		WAT		8 WAT		12 WAT	
	Branch (no.)	GI (cm)	Branch (no.)	GI (cm)	Branch (no.)	GI (cm)	Branch (no.)	GI (cm)
Propagation								
Cutting	1.9 b[z]	14.0 a	-[y]	19.0 a	2.7 b	23.8 a	3.1 b	25.80 a
in vitro	4.1 a	12.7 b	-	15.9 b	4.7 a	20.1 b	5.3 a	24.03 b
Significance	***	***	-	***	***	***	***	**
PGR treatment								
Water	—[x]	—	-	20.2 a	3.6 b	25.1 a	3.9 b	27.1 a
Augeo	—	—	-	17.6 bc	3.5 b	22.6 b	3.8 b	25.4 ab
Configure	—	—	-	18.1 ab	3.1 b	24.2 ab	3.7 b	27.1 a
Topflor	—	—	-	15.7 c	3.5 b	18.3 c	4.5 ab	21.6 c
Prune	—	—	-	15.8 c	4.8 a	19.7 c	5.2 a	23.4 bc
Significance	—	—	-	***	***	***	**	***

[z]Means within a column followed by the same letter were not significantly different (Tukey's HSD α = 0.05).
[y]Dashes indicate interaction between propagation method and PGR applied.
[x]Analysis not conducted because treatments had not been applied on this date.

Table 6: Interaction of propagation method and PGRs on phytotoxicity of *Rhododendron* 'Roseum Elegans' at 2 weeks after treatment.

	Phytotoxicity	
PGR treatment	Cutting	in vitro
Water	0.1 b[z]	0.0 b
Augeo	1.0 ab	0.0 b
Configure	2.2 a	0.0 b
Topflor	1.0 ab	0.0 b
Pruned	0.6 b	0.0 b
Significance	*	

[z]Means within a column followed by the same letter were not significantly different (Tukey's HSD α = 0.05).

Table 7. Phytotoxicity at 2 weeks after treatment (WAT), and plant visual quality at 12 WAT of in vitro- or cutting-propagated *Rhododendron* 'Roseum Elegans' in response to PGR treatments.

Treatment	Phytotoxicity[z]	Quality
Propagation		
Cutting	-	2.5 b[y]
in vitro	-	2.9 a
Significance	-	*
PGR treatment		
Water	-	2.5 ab
Augeo	-	2.3 b
Configure	-	2.9 ab
Topflor	-	3.3 a
Prune	-	2.5 b
Significance	*	***

[z]Dashes indicate interaction between propagation method and PGR applied
[y]Means within a column followed by the same letter were not significantly different (Tukey's HSD α = 0.05).

Impact of Dikegulac Sodium and Pinching on the Branching of *Hydrangea macrophylla* 'Merritt's Supreme'

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Significance to Industry: Hydrangeas are popular ornamental plants. *Hydrangea macrophylla* is the most widely grown hydrangea with over 600 cultivars. *Hydrangea macrophylla* 'Merritt's Supreme' is one of the most common cultivars for the production of florists' hydrangea. In order to produce a well-branched plant, growers mainly rely on hand pinching or pruning to promote branching. However, hand pinching or pruning is labor intensive and increases production cost. As an alternative, different plant growth regulators (PGR) have been used to control plant height and promote branching. However, the efficacy of PGR varies largely with species, cultivars, and environmental conditions. Dikegulac sodium (Augeo™) is labeled to reduce or break apical dominance in plant shoots and to enhance lateral branching. Al-Juboory and Williams (1) observed that dikegulac sodium stimulated branching but reduced branch length in golden pothos (*Scindapsus aureus*). In Boston fern, dikegulac sodium had the potential to improve the appearance and aesthetic quality (2). There has been limited research on the effect of dikegulac sodium on hydrangea branching. In this study, we investigated the effect of different rate of dikegulac sodium on promoting hydrangea branching. Results showed that dikegulac sodium applied as a foliar spray at 400, 800, and 1600 ppm promoted branching on unpinched *hydrangea macrophylla* 'Merritt's Supreme'.

Nature of Work: *Hydrangea macrophylla* cuttings received on May 3, 2012 from commercial company were dipped into 1000 ppm IBA solution and stuck into propagation cells (6.5 cm × 6.5 cm × 7.5 cm) filled with a mixture of perlite: Sunshine Mix No. 4 (SunGro Hort., Bellevue, WA) at 1:1 volume ratio. Rooted cuttings were transplanted to a #1 gallon (2.6-L) container filled with Sunshine Mix No. 4 on June 19, 2012 and irrigated with a nutrient solution made by adding 0.72 $g \cdot L^{-1}$ of 15N-2.2P-12.5K (Peters 15-5-15, Scotts, Marysville, OH) to reverse osmosis water. Micromax® micronutrients (Scott, Marysville, OH) were added at 4 g per pot. On June 26, 2012, half of the plants (208 plants in total) were pinched to leave two nodes. On July 12, 2012, Augeo™ (18.5% dikegulac sodium; OHP, Inc., Mainland, PA) application was made as a foliar spray at 400, 800, and 1600 ppm to both pinched and unpinched plants, 26 plants per treatment. Phytotoxicity reflected as leaf yellowing and distortion

were rated 2 and 6 weeks after Augeo™ application on a scale of 0 to 10 with 0 = no phytotoxicity, 1 = 10% leaves affected, and 10 = 100% leaves affected (completely killed). Eighty days after treatment, plant height (cm), two perpendicular width (cm), and number of branches were measured, while leaf area (cm^2) and dry weight (g) were measured of 10 randomly selected plants per treatment. Growth index was calculated as (height + width 1 + width 2)/3. Height was measured from the pot rim to the tallest point of the plant. Visual quality was rated at 80 days after the treatment based on a scale of 1 to 7, where 1 = significantly worse than untreated, 2 = moderately worse than untreated, 3 = slightly worse than untreated, 4 = no difference from untreated, 5 = slightly better than untreated, 6 = moderately better than untreated, and 7 = significantly better than untreated. In order to determine the blooming responses, plants were moved to a cooler at 4 °C on December 4, 2012 and moved back to the greenhouse on March 8, 2013. Plants were manually defoliated before putting into the cooler. On May 7, 2013, plant height, growth index, number of branches and flowers, and diameter of flowers were measured. The temperatures in the greenhouse were maintained at 28.0 ± 3.4 °C and 25.5 ± 3.0 °C (mean ± standard deviation) during the day and 25.4 ± 2.4 °C and 22.2 ± 1.6 °C at night from June 19 to October 1, 2012 and from March 8 to May 7, 2013, respectively. The daily light integral (photosynthetically active radiation) was 17.9 ± 3.3 and 22.3 ± 4.0 $mol \cdot m^{-2} \cdot d^{-1}$ from June 19 to October 1, 2012 and from March 8 to May 7, 2013, respectively.

Results and Discussion: Two weeks after treatment, phytotoxicity symptoms of leaf yellowing and distortion were more severe at higher concentrations of Augeo™ (Table 1 and 2). The symptoms became much less obvious 6 weeks after the application at all concentrations compared to those at 2 weeks. At 400 ppm, there were little or no leaf yellowing and distortion 6 weeks after the treatment. Pinching did not affect leaf yellowing, while it reduced the symptom of leaf distortion. Phytotoxicity is a concern with Augeo™ application (3), but the severity of symptom usually decreases over time as seen in this study. In another study in Little Lime™ hardy hydrangea (4), phytotoxicity symptoms disappeared 16 weeks after treatment.

Eighty days after Augeo™ treatment, pinched plants were taller and bigger (greater height and growth index) than unpinched ones at lower Augeo™ concentrations (untreated and 400 ppm) (Table 1 and 3). Pinching and Augeo™ application interactively affected branching. For both pinched and unpinched plants, number of branches was greater for plants treated with Augeo™, especially for unpinched plants. Pinching did not affect visual quality, leaf area, and dry weight (Table 1). Visual quality, leaf area, and dry weight decreased linearly as Augeo™ concentration increased (Table 3).

After cold treatment, the effects of Augeo™ application and pinching were less obvious (Table 1 and 4). For example, pinching did not affect plant height, growth index, number of flowers and flower size assessed on May 7, 2013 (10 months after the treatment). Augeo™ application did not affect plant height, growth index, and number of branches. For unpinched plants, number of flowers was lower for untreated plants

compared to Augeo™ treated ones. For pinched plants, number of flowers and flower size were smallest for plants treated at 800 and 1600 ppm Augeo™.

In summary, pinching increased branching and promoted growth in *Hydrangea macrophylla* 'Merritt's Supreme'. Foliar spray with Augeo™ enhanced branching, especially on unpinched plants. However, high concentration of Augeo™ at 1600 ppm did not show any advantage over the lower concentrations.

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Table 1. A summary of ANOVA on 1) phytotoxicity assessed 2 weeks and 6 weeks after treatment, 2) plant height, growth index, number of branches, visual quality, leaf area, and dry weight assessed 80 days after treatment, and 3) plant height, growth index, number of branches, number of flowers, and diameter of flowers assessed on May 7, 2013 (10 months after treatment) of *Hydrangea macrophylla* 'Merritt's Supreme applied with dikegulac sodium (Augeo™) as a foliar spray.

Phytotoxicity				
Treatment	2 weeks		6 weeks	
	Yellowing	Distortion	Yellowing	Distortion
Pinch	NS[z]	<0.0001	NS	<0.0001
Augeo™	<0.0001	<0.0001	<0.0001	<0.0001
Pinch x Augeo™	0.0147	NS	NS	0.0001

Growth, branching, and visual quality 80 days after treatment						
	Height	Growth index	Number of branches	Visual quality	Leaf area	Dry weight
Pinch	0.006	<0.0001	0.0066	NS	NS	NS
Augeo™	<0.0001	<0.0001	<0.0001	0.0003	<0.0001	<0.0001
Pinch x Augeo™	NS	<0.0001	<0.0001	NS	0.0216	NS

Blooming and growth responses assessed 10 months after treatment					
	Height	Growth index	No. of branches	No. of flowers	Flower diameter
Pinch (P)	NS	NS	0.0006	NS	NS
Augeo™ (A)	0.0579	NS	NS	NS	0.0261
P x A	NS	0.0235	NS	0.0023	NS

[z]NS: treatment effect was not significant at α = 0.05.

Table 2. Phytotoxicity rating scores of *Hydrangea macrophylla* 'Merritt's Supreme' applied with dikegulac sodium (Augeo™) as a foliar spray. Linear and quadratic regression results are presented.

			Yellowing[z]		
Appl. rate	2 weeks			6 weeks	
(ppm)	Unpinched	Pinched	Unpinched	Pinched	Pooled
0	0.0	0.0	0.0	0.0	0.0
400	5.2	2.0	0.0	0.3	0.2
800	7.4	7.3	2.0	1.5	1.8
1600	8.0	9.1	3.8	4.0	3.9
Linear	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Quadratic	<0.0001	0.0002	NS[y]	NS	NS
			Distortion		
Appl. Rate		2 weeks		6 weeks	
(ppm)	Unpinched	Pinched	Pooled	Unpinched	Pinched
0	0.0	0.0	0.0	0.0	0.0
400	3.8	1.1	2.5	0.0	0.0
800	7.5	2.5	5.0	1.4	0.4
1600	6.4	5.1	5.7	2.3	0.9
Linear	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Quadratic	<0.0001	NS	<0.0001	NS	NS

[z]Rating standard for phytotoxicity (yellowish leaves and distortion, curled leaves): percentage of phytotoxicity: score 0 = 0%, score 1 = 10%, score 2 = 20%, score 10 = 100% (complete kill).
[z]NS: treatment effect was not significant at α = 0.05.

Table 3. Effect of dikegulac sodium (Augeo™) applied to *Hydrangea macrophylla* 'Merritt's Supreme'as a foliar spray on visual quality, leaf area, and dry weight (DW), and the increases in plant height, growth index, and number of branches assessed on October 1, 2012 (80 days after treatments). Linear and quadratic regression results are presented.

	Height (cm)[z]		Growth index (cm)		Number of branches	
	Unpinched	Pinched	Unpinched	Pinched	Unpinched	Pinched
0	12.9	14.5	13.4	18.8	1.4	4.8
400	15.1	14.8	14.3	15.8	5.1	5.1
800	9.0	11.8	10.2	11.9	5.3	5.3
1600	10.2	10.4	9.7	8.5	5.9	5.0
Linear	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	NS
Quadratic	NS[y]	NS	NS	0.00754	<0.0001	NS

	Visual quality		Leaf area (cm^2)		DW (g)
	Unpinched	Pinched	Unpinched	Pinched	Pooled
0	4.0	4.2	1633	2103	23.4
400	3.9	4.0	1913	1908	22.2
800	3.3	3.4	1469	1552	14.7
1600	2.8	2.8	1352	1177	11.3
Linear	<0.0001	<0.0001	0.0175	<0.0001	<0.0001
Quadratic	NS	NS	NS	NS	NS

[z]Plant height: from pot rim to the tallest point of the plant; visual scores: 1 = significantly worse than untreated, 2 = moderately worse than untreated, 3 = slightly worse than untreated, 4 = no difference from untreated, 5 = slightly better than untreated, 6 = moderately better than untreated, and 7 = significantly better than untreated.
[y]NS: treatment effect was not significant at $\alpha = 0.05$.

Table 4. Effect of dikegulac sodium (Augeo™) applied as a foliar spray to *Hydrangea macrophylla* 'Merritt's Supreme'on plant height, growth index, number of branches, number of flowers, and diameter of flowers assessed on May 7, 2013 (10 months after treatment). Plants were placed in a 4 ºC cooler from December 4, 2012 to March 8, 2013. Linear and quadratic regression results are presented.

	Height (cm)[z]		Growth index (cm)		Number of branches	
	Unpinched	Pinched	Unpinched	Pinched	Unpinched	Pinched
0	18.5	17.1	27.5	28.9	4.4	6.5
400	20.7	19.5	30.0	32.1	6.9	8.9
800	18.0	18.9	31.7	31.3	7.3	8.0
1600	17.0	14.6	30.8	25.5	5.9	6.4
Linear	NS[y]	NS	NS	NS	NS	NS
Quadratic	NS	0.0158	NS	0.0116	0.0002	0.0094

	Number of flowers		Diameter of flowers	
	Unpinched	Pinched	Unpinched	Pinched
0	2.4	4.1	13.8	13.4
400	3.7	4.3	13.2	13.1
800	4.4	4.8	12.5	11.6
1600	4.0	2.5	13.0	11.8
Linear	0.0305	0.0317	NS	0.0022
Quadratic	0.0225	0.0252	NS	NS

[z]Plant height: from pot rim to the tallest point of the plant
[y]NS: treatment effect was not significant at α = 0.05.