Growth Regulators

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Impact of Various PGRs on Postproduction Quality of Potted Geraniums

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Index Words: Plant Growth Regulator, Benzyladenine, Cytokinin, Gibberellin, Postharvest, 1-MCP, Abscission, Ethylene, *Pelargonium* x *hortorum*, *Pelargonium peltatum L.*

Significance to Industry: Geraniums are one of the most popular flowering plants in the U.S. Relatively short postproduction life characterized by flower abscission and leaf yellowing reduces consumer satisfaction and marketability of geraniums. Ethylene-induced petal abscission during shipping and handling can be prevented by the application of 1-MCP. However, 1-MCP does not improve postproduction quality of geraniums in the absence of ethylene. In this study, various PGRs were evaluated to enhance postproduction quality of ivy (*Pelargonium peltatum L.*) and zonal (*Pelargonium x hortorum* L.H. Bailey) geraniums. GA_{4+7} significantly increased the number of florets and greatly reduced leaf yellowing in both geraniums, resulting in higher visual quality compared to other treatments. It also increased the size of florets and length of pedicels, hence a larger inflorescence. Our results suggest that GA_{4+7} enhances postproduction quality in geraniums.

Nature of Work: Geraniums are popular flowering potted plants with attractive flower heads and leaves, and wide range of floret color. Postproduction quality of potted geraniums is limited by rapid petal abscission induced by exposure to ethylene during shipping and postproduction leaf yellowing. 1-MCP prevents floral abscission in various flowering potted plants in the presence of exogenous ethylene (6). However, it does not improve postproduction quality when ethylene is not present (2,7).

GA_{4+7} plus BA enhances postproduction quality in many flowering potted plants (3,5). GA_{4+7} or 6-benzyladenine (BA) alone also prolonged the longevity of lilies (5), carnations (1) and roses (4). The objective of this study was to determine the effects of various plant growth regulators on the production quality of geraniums.

Rooted cuttings of ivy geranium 'Tutti-Frutti' and zonal geranium 'Tango' were potted in 15-cm (1.5-L) azalea pots filled with MetroMix 360 and placed in a greenhouse maintained at 70ºF (21°C) day/61ºF (16ºC) night with natural photoperiod and full natural light. The plants were alternately fertilized during irrigation with Peters Professional Foliar Feed, 27N-6.6P-10K, and Miracle-Gro Professional Excel, 15N-2.2P-12.5K CAL-MAG (Scotts-Sierra, Marysville, OH).

When plants had 2 to 3 open florets, whole plants were sprayed with 25 mL of 0 (distilled water), 100 ppm GA_{4+7} plus BA (Fascination, Valent USA), 100 ppm GA_{4+7}

(ProVide, Valent USA) or 100 ppm BA (MaxCel, Valent USA) and kept in the greenhouse overnight to allow leaves to dry. Other sets of plants were placed in a 106 × 74 × 64 cm (500-L) chamber for 1-MCP (EthylBloc, Floralife Inc.) treatment. The container was sealed after EthylBloc powder was placed in a suspended weighing boat from the ceiling of the container. Buffer solution was injected with a syringe to release 1 ppm 1-MCP. Plants were treated with 1-MCP for 15 hours at a temperature of 72.2 ± 0.2ºF (22.4 ± 0.1ºC). The plants were then removed from the chamber and kept in the greenhouse one day. All plants were placed in cardboard boxes and moved to a room maintained at 68ºF (20ºC) to simulate transport for 3 days in darkness. Plants were then moved and placed under 2 layers of shade cloth for a simulated retail display in order to evaluate postproduction performance. The temperature and relative humidity at canopy height was 66-87ºF (19-30ºC) with 53 ± 25% RH and natural light conditions. Plants were irrigated as needed.

Visual quality on a scale of 0 to 10 (with 0 being unsalable and 10 being highly attractive) and phytotoxicity (with 0 being no phytotoxicity and 10 being plant death) were evaluated. Plant height, inflorescence diameter, and number of open florets were measured before and after simulated shipping. The postproduction longevity was considered completed when less than five florets remained on the plant. The severity of leaf yellowing was recorded during the postproduction period on a scale of 0% (no leaf chlorosis) to 100% (100% leaf chlorosis).

Treatments were arranged in a completely randomized design with eight pots per treatment. Data were analyzed with analysis of variance (ANOVA) by the General Linear Models Procedure (Minitab, Minitab Inc.) with a significance level of 0.05. Multiple mean comparisons were conducted with Tukey's Test when there were significant treatment effects.

Results and Discussion: Phytotoxicity caused by BA appeared before simulated transport on open florets at the time of spray (Fig. 1 A, B). The symptoms were bleached spots or areas along the petal edges in both cultivars. All petals showing phytotoxicity abscised during simulated shipping. Phytotoxicity caused by GA_{4+7} plus BA, however, appeared after simulated transport as necrotic areas on the receptacles of unopened buds and leaves in 'Tutti-Frutti' (Fig. 1 C, D), and along the leave edges in 'Tango' (Fig. 1F).

Florets showing phytotoxicity after BA sprays abscised petals during simulated transport in both 'Tutti-Frutti' and 'Tango'. In 'Tutti-Frutti', the petal abscission rate of BA-treated florets was significantly higher than in controls or the 1-MCP treatment, and sprays with GA_{4+7} plus BA or GA_{4+7} tended to increase abscission rate (data not shown). In 'Tango', however, old florets abscised petals during simulated transport regardless of treatment, resulting in no significant difference in petal abscission rates among treatments (data not shown). The abscission rate of 1-MCP treated plants was not different from controls in both cultivars.

GA_{4+7} significantly increased the number of florets (Fig. 3) and greatly reduced leaf yellowing in both cultivars (Table 1), resulting in higher visual quality compared to other treatments (Table 1). Further, GA_{4+7} increased the size of florets and length of pedicels, hence a larger inflorescence (Fig. 3). By itself, BA had no effect on any quality measures in both cultivars. Similarly, 1-MCP did not affect petal abscission during simulated transport or enhancement of postproduction quality in both cultivars.

In 'Tutti-Frutti', GA_{4+7} plus BA sprays significantly increased floret number, somewhat increasing postproduction longevity of the plants (Fig. 2). In 'Tango', however, both GA_{4+7} plus BA and GA_{4+7} sprayed plants had significantly higher floret number from 7 days, resulting in greater enhancement of postproduction longevity (Fig. 2). Meanwhile, control, BA, or 1-MCP treated plants has fewer florets from 7 days and remained low in floret number for the rest of experimental period (data not shown).

Our results suggest that GA_{4+7} enhances postproduction quality in geraniums. Further research will be needed to determine concentrations and application details for maximum effectiveness.

Literature Cited

1. Bichara, A.E. and J. van Staden, 1993. The effect of aminooxyacetic acid and cytokinin combinations on carnation flower longevity. Plant Growth Regul. 13:161–167.
2. Kim, H.J., R. Craig, and K.M. Brown. 2007. Ethylene resistance of regal pelargonium is complemented but not replaced by 1-MCP. Postharvest Biol. Technol. 45:66-72.
3. Kim, H.J. and W.B. Miller. 2007. Effects of GA_{4+7} and benzyladenine application on postproduction quality of 'Seadov' pot tulip flowers. Postharvest Biol. Technol. (doi:10.1016/j.postharvbio.2007.08.004)
4. Mayak, S. and A.H. Halevy. 1970. Cytokinin activity in rose petals and its relation to senescence. Plant Physiol. 46:497–499.
5. Ranwala, A.P and W.B. Miller. 1998. $Gibberellin_{4+7}$, benzyladenine, and supplemental light improve postharvest leaf and flower quality of cold-stored 'Star Gazer' hybrid lilies. J. Am. Soc. Hort. Sci. 123:563–568.
6. Serek, M., E.C. Sisler, and M.S. Reid. 1994. Novel gaseous ethylene binding inhibitor prevents ethylene effects in potted flowering plants. J. Am. Soc. Hort. Sci. 119:1230–1233.
7. Serek, M. and E.C. Sisler. 2001. Efficacy of inhibitors of ethylene binding in improvement of the postharvest characteristics of potted flowering plants. Postharvest Biol. Technol. 23:161–166.

Table 1. Leaf yellowing and visual quality of ‘Tutti-Frutti’ and ‘Tango’ geraniums in a simulated retail display at 7 days after spraying with distilled water (control), 100 ppm each GA_{4+7} plus BA, 100 ppm GA_{4+7}, 100 ppm BA, or treated with 1 ppm 1-MCP for 15 hours followed by simulated transport for 3 days. Values shown are means of 8 plants.

Cultivar	Treatment	Leaf yellowing (%)		Visual quality	
‘Tutti-Frutti’	Control	32.5	c[z]	7.0	a
	Fascination	3.1	a	9.1	bc
	GA_{4+7}	3.1	a	9.9	c
	BA	18.8	b	8.4	b
	1-MCP	33.8	c	6.1	a
‘Tango’	Control	50.6	c	0.4	a
	Fascination	15.6	a	5.6	b
	GA4+7	10.0	a	6.9	b
	BA	40.6	bc	1.4	a
	1-MCP	37.5	b	0.8	a

[z] Means within columns followed by different letters indicates significant difference at *P* <0.05 according to Tukey's Test.

Fig. 1. Phytotoxicity caused by 100 ppm BA appeared before simulated transport (A and B) shown as bleached areas in petals of (A) ‘Tutti-Frutti’ and (B) ‘Tango’ geraniums two days after spraying with 100 ppm BA in open florets. Phytotoxicity caused by 100 ppm GA_{4+7} plus BA appeared after simulated transport (C, D and E): it developed on (C) the receptacles of unopened buds and (D) leaves of ‘Tutti-Frutti’ and (E) only on the leaves of ‘Tango’.

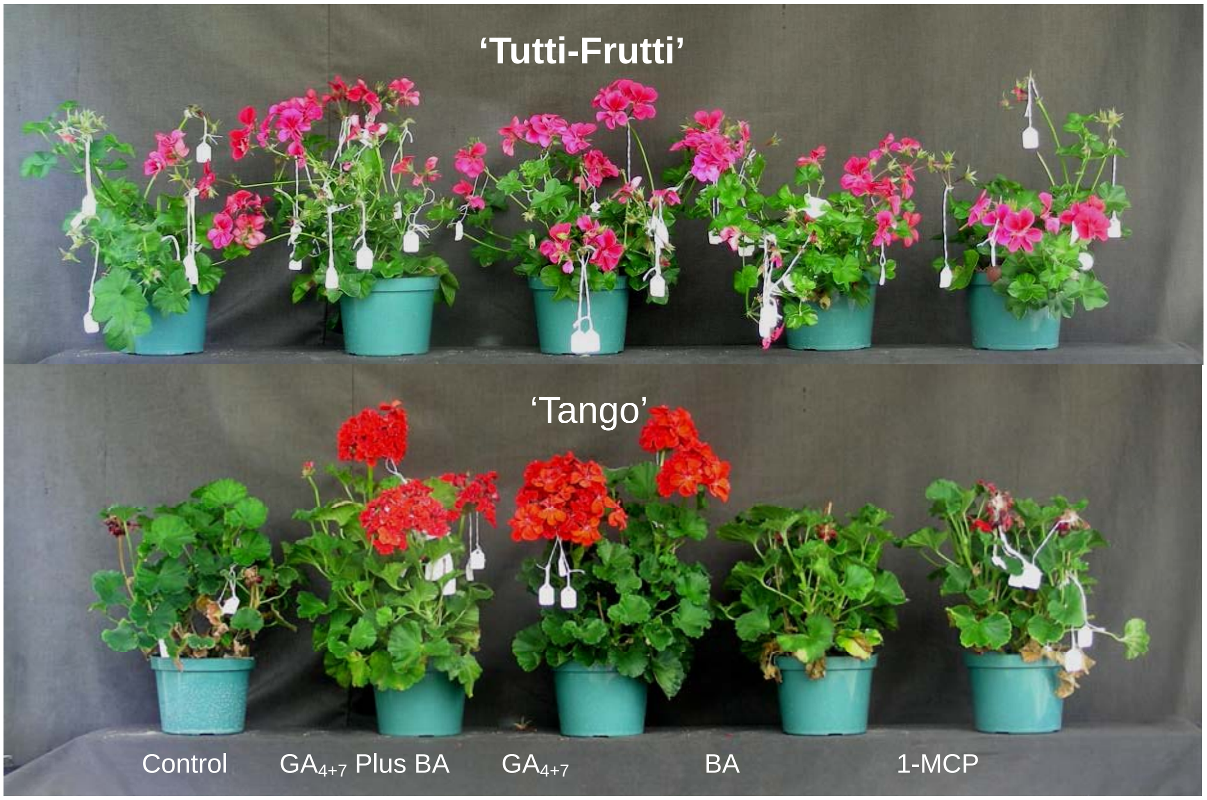

Fig. 2. 'Tutti-Frutti' and 'Tango' geraniums at Day 14 in a simulated retail display after treatment with (L to R): distilled water, 100 ppm each GA_{4+7} plus BA, 100 ppm BA, 100 ppm GA_{4+7} or treated with 1 ppm 1-MCP for 15 hrs followed by simulated transport for 3 days.

Fig. 3. Inflorescence of 'Tango' geranium 10 days after spraying with distilled water, 100 ppm GA_{4+7} plus BA or 100 ppm GA_{4+7} followed by simulated transport for 3 days. (A) florets sprayed with distilled water showed stunted growth, (B) spray with 100 ppm each GA_{4+7} plus BA induced unusual small-sized, Kalanchoe-like florets, and (C) spray with GA_{4+7} stimulated growth of florets that were open during and after simulated transport, increasing floret size. Florets open long after simulated transport displayed small, Kalanchoe-like florets. Therefore, the inflorescence was a mixture of various sizes of florets.

Liner Drenches of Trinexapac-ethyl Reduce Height of Ornamental Grasses

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Index Words: Primo MAXX™; *Arundo*; *Calamagrostis*; *Cortaderia*; *Miscanthus*; *Panicum*; *Pennisetum*

Significance to Industry: Ornamental grasses are popular perennials and annuals for use in landscapes and container gardens. These grasses often grow fast and easily outgrow containers during nursery production. Managing the growth rate of annuals and perennials with plant growth regulators has become an important production strategy in nurseries and greenhouses. We evaluated the growth and development of six genera of popular ornamental grasses drenched with trinexapac-ethyl (Primo MAXX™) at 0, 15, 25, 35 and 45 oz/100 gallon at transplanting. Liner drenches of trinexapac-ethyl applied at 35 and 45 oz/100 gallons effectively reduced height up to eight weeks after treatment in all grass species except *Pennisetum setaceum* 'Rubrum', which did not respond to drench applications. A drench of trinexapac-ethyl to perennial grass liners at transplanting could be an effective management practice for height control during production.

Nature of Work: The popularity of ornamental grasses used in American landscapes has increased dramatically in past decades (2). Most ornamental grasses are cultivated in residential and commercial plantings because they thrive in full sun and dry conditions with high heat and humidity. Because of the range in size, hardiness, color, form, and texture, ornamental grasses are versatile for use during many seasons of the year. The popularity of these grasses has been discussed previously (3) and the number of species available and their use has been documented (6). Even the 2009 perennial plant of the year is an ornamental grass: *Hakonechloa macra* 'Aureola'.

There are several nurseries with an emphasis on ornamental grass production including Emerald Coast Growers and Hoffman Nurseries. Some of these companies have expressed an interest in using plant growth regulators during liner production to manage the height of their grass crops. Previous research has shown the potential for plant growth regulation of ornamental grasses during production (9,10). Additional research has been conducted in turfgrass species to reduce height and suppress growth using trinexapac-ethyl (Primo MAXX™) (1,4,5). In some cases trinexapac-ethyl was shown to improve the quality and drought tolerance of turfgrass (7,8).

The objective of this study was to determine the effect of trinexapac-ethyl at selected drench rates on phytotoxicity, height, and tiller number in ornamental grasses. Liners of

Arundo donax 'Variegata', *Calamagrostis* x *acutiflora* 'Overdam', *Cortaderia selloana* 'Rosea', *Miscanthus sinensis* 'Gracillimus', *Panicum virgatum*, and *Pennisetum setaceum* 'Rubrum' were received on April 15, 2008. Liners were soaked in trinexapac-ethyl treatments at 0, 15, 25, 35 and 45 oz/100 gallons for five minutes. Liners were then potted into one-gallon containers using a mix containing 75% bark fines with 25% Fafard 3B. Plants were topdressed with 3-4 month Osmocote controlled-release fertilizer at transplanting. Plants were grown outside on nursery fabric and were watered daily by hand. Data was collected on plant injury and height at 0, 14, 28, 42 and 56 days after treatment (DAT). Injury ratings were rated visually on a scale of 0 to 10, where 0 = no injury and 10 = plant death. Tiller number was counted at the termination of the trial at 56 DAT.

Statistical analysis: Treatments were arranged by species in a completely randomized design with twelve replications. Data were analyzed using ANOVA and means were separated using Fisher's protected LSD at $P = 0.05$.

Results and Discussion: No injury was observed from drench treatments in the species tested at any drench rate (data not shown). Height of the ornamental grasses four, eight and twelve weeks after treatment (WAT) are presented in Table 1. There were significant decreases in height from trinexapac-ethyl applications compared to controls in all grass species except the annual grass *Pennisetum setaceum* 'Rubrum' (Table 1). In most species, trinexapac-ethyl applied at 35 or 45 oz/100 gallons was most effective at reducing height up to 8 WAT. Height of *Calamagrostis* x *acutiflora* 'Overdam' and *Miscanthus sinensis* 'Gracillimus' was reduced up to 12 WAT with drenches of trinexapac-ethyl applied 35 oz/100 gallons. Application of trinexapac-ethyl to ornamental grass species did not significantly increase tiller production (data not shown).

Our results are consistent with previous research in turf and ornamental grasses evaluating the effects of trinexapac-ethyl on height (4,5,7,8,9,10). However, previous research has evaluated trinexapac-ethyl as a spray application, not as a drench application. Future research will evaluate the same rates of trinexapac-ethyl on flowering and drought tolerance in these ornamental grasses. Additional research will evaluate the number of tillers late in the growing season after applications of trinexapac-ethyl. From this data, and from previous research we believe that trinexapac-ethyl may be an effective growth regulator for height management in ornamental grass production.

Literature Cited:

1. Beasley, J.S. and B.E. Branham. 2007. Trinexapac-ethyl and paclobutrazol affect Kentucky bluegrass single-leaf carbon exchange rates and plant growth. Crop Sci. 47:132-138.
2. Cameron, A. 2004. Ornamental Grasses: A New Wave in Floriculture Crops. Greenhouse Product News 14:9.
3. Dana, M.N. 2002. Ornamental grasses and sedges as new crops. p. 473–476. In: J. Janick and A. Whipkey (eds.), Trends in New Crops and New Uses. ASHS Press, Alexandria, VA.

4. Ervin, E.H. and A.J. Koski. 1998. Growth responses of *Lolium perenne* L. to trinexapac-ethyl. HortScience 33:1200-1202.
5. Ervin, E.H., C.H. Ok, B.S. Fresenburg, and J.H. Dunn. 2002. Trinexapac-ethyl restricts shoot growth and prolongs stand density of 'Meyer' zoysiagrass fairway under shade. HortScience 37:505-505.
6. Greenlee, J. 1992. The Encyclopedia of Ornamental Grasses. Rodale Press, Emmaus, PA.
7. McCann, S.E. and B. Huang. 2007. Effects of trinexapac-ethyl foliar application on creeping bentgrass responses to combined drought and heat stress. Crop Sci. 47:2121-2128.
8. McCullough, P.E., H. Liu, L. McCarty, and J.E. Toler. 2007. Trinexapac-ethyl application regimens influence growth, quality, and performance of Bermuda grass and creeping bentgrass putting greens. Crop Sci. 47:2138-2144.
9. Trader, B. and M. Gu. 2008. Plant growth regulation of ornamental grasses. Proc. South. Nurs. Assoc. 53:16-18.
10. Whipker, B.E., I. McCall, C. Adkins, and J. Sellmer. 1999. Research progress report: Ornamental grass growth regulator study. North Carolina Flower Growers Bul. 44:3-5.

Table 1. Height (in centimeters) of six species of ornamental grasses at 4, 8, and 12 weeks after treatment (WAT) with trinexapac-ethyl applied as a drench to liners prior to transplanting into one-gallon containers.

Rate of trinexapac-ethyl	Height (cm)		
oz/100 g	4 WAT	8 WAT	12 WAT
	Arundo donax 'Variegata'		
0	46.4 ab^{z}	47.6 a	67.3 a
15	50.0 a	42.7 bc	69.0 a
25	46.3 ab	44.3 ab	65.6 a
35	46.4 a	40.5 c	68.1 a
45	40.7 b	44.2 ab	65.9 a
	Calamagrostis x *acutiflora* 'Overdam'		
0	21.7 a	30.8 a	36.2 a
15	19.0 b	19.9 b	31.3 a
25	16.3 c	15.3 c	24.3 b
35	18.9 b	19.1 b	24.9 b
45	19.2 b	19.6 b	32.2 a
	Cortaderia selloana 'Rosea'		
0	36.1 a	70.6 a	80.3 ab
15	33.0 b	57.9 b	81.1 a
25	34.6 ab	54.6 bc	76.6 abc
35	34.0 b	54.6 bc	72.1 bc
45	35.0 ab	48.9 c	68.4 c
	Miscanthus sinensis 'Gracillimus'		
0	28.9 b	41.1 a	75.3 a
15	25.3 c	34.2 b	70.3 ab
25	33.1 a	34.2 b	64.1 c
35	32.3 a	32.2 b	69.1 bc
45	31.3 ab	32.2 b	72.5 ab
	Panicum virgatum		
0	29.8 a	50.0 a	61.5 a
15	21.3 bc	41.8 b	54.6 ab
25	20.2 bc	38.8 b	47.8 b
35	25.3 ab	39.3 b	53.4 ab
45	16.9 c	34.3 b	47.6 b
	Pennisetum setaceum 'Rubrum'		
0	29.3 a	37.8 a	54.5 a
15	28.2 a	32.9 b	61.2 a
25	29.8 a	35.5 ab	56.7 a
35	28.3 a	34.5 b	56.3 a
45	30.5 a	37.4 a	60.0 a

^{z}Means within a column and species followed by the same letter do not differ significantly according to Fisher's protected LSD

The Use of Plant Growth Regulators in Container-Grown Winter Red® Holly

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Index words: Winter Red® Holly, Plant Growth Regulators, Woody Ornamentals, Branching

Significance to Industry: This study examined the effectiveness of branch-inducing treatments using several plant growth regulators (PGRs) in the production of Winter Red® holly. Growers of Winter Red® holly who want to induce branching may well be able to apply Atrimmec prior to sale or earlier in the season ahead of sale as time diminished phytotoxic effects. Pruning was ineffective and reduced the number of berries. Cyclanilide treatments were no better than spraying with water alone.

Nature of Work: Growth regulators have been used to increase branching and promote elongation of axillary shoots in many foliage, bedding, and woody plants in order to produce more desirable plants and shorten production time (3). Studies indicate that cyclanilide has the potential to induce lateral branching without mechanical pruning during nursery container production (1). Other studies show that a single application of Promalin (BA + GA4/7) or BA alone at 2000 to 5000 ppm increased branching in other woody ornamentals such as ‘Helleri’ holly, ‘Stoke’s Dwarf' holly, and ‘Formosa’ azalea (2). The objective of this study was to evaluate the effectiveness of several plant growth regulator (PGR) treatments on branching of *Ilex verticillata* Winter Red®.

On April 4, 2008, well-rooted cuttings of *Ilex verticillata* Winter Red® were transplanted into trade one-gallon containers (Classic 500; Nursery Supplies Inc., McMinnville, OR) with a custom blend (no lime) of a pine bark-based substrate (Barky Beaver Professional Grow Mix; Barky Beaver Mulch and Soil Mix, Inc., Moss, TN). Controlled-release fertilizer (19-4-8, 5-6 month release; Harrell’s Inc., Sylacauga, AL) was surface-applied at a rate of 12 grams per 1-gallon container on April 8, 2008. On July 3, 2008, the plants were repotted into 3-gallon containers. Plants were fertilized again on July 18, 2008 with a controlled-release fertilizer (15-9-12, 2-3 month release; Osmocote® Plus; The Scotts Co., Marysville, OH), at the medium rate of 30 grams per 3 gallon container. Cyclic irrigation was provided 3 times per day for 3 minutes with micro irrigation. Plants were maintained in a Quonset hut overwintering structure until May 6, 2008 when they were moved to a gravel pad at the UK Horticulture Research Farm in Lexington, KY. Containers were hand-weeded for the duration of the experiment.

Treatments were: Cyclanilide (2 applications at 100 ppm) with no hand pruning, Cyclanilide (2 applications at 100 ppm) with hand pruning, Atrimmec (2 applications at

3800 ppm) with no hand pruning, Atrimmec (2 applications at 3800 ppm) with hand pruning, and two controls for comparison which included hand pruning alone and spray application of water alone. Plants received the first foliar spray application on July 11, 2008, after plants were established in their containers and growing actively. A CO_2 backpack sprayer was used to make the applications. The spray pressure was 10 psi. On August 11, 2008, the second application was made using the same sprayer and pressure.

Plant height (from surface of substrate to the tip of the longest shoot), width (the widest point of the canopy), and branch number were measured and recorded on June 23 (initiation of the experiment), Sept. 9, and Nov. 6, 2008. A growth index was calculated as (height + width)/2. For phytotoxicity assessment, a scale of 0 (no phytotoxicity) to 10 (plant death) was used. Assessments were made on July 18 and Aug. 1, 2008 following the first application and on Aug. 21 and Sept. 26, 2008 following the second application. A quality rating (Fig. 1) was made on Oct. 2, 2008 to illustrate the effect of the treatments on quality of the canopy. A rating scale of 1 (least desirable plant having few branches or just one long branch, often curved at the top) to 5 (excellent, full, compact, and very desirable plant for the landscape) was used. The total number of berries was determined on Nov. 5 and 6, 2008.

Results and Discussion: Beginning three weeks after the first application of PGRs, plants in the two Atrimmec treatments exhibited symptoms of phytotoxicity. The highest phytotoxicity rating was reached one week after the second PGR application with ratings of 6.33 without pruning and 6.75 with pruning (Table 1, Fig. 2). By the sixth week after the second application of PGRs, plants seemed to have outgrown the chemical injury with ratings reduced to 2.83 and 3.00, respectively, for treatments of Atrimmec without hand pruning and Atrimmec with hand pruning. Growers who sell cut stems may tolerate some phytotoxicity on older foliage since that foliage is typically stripped off the stem prior to sale.

At twelve weeks after treatment (WAT), total branch number varied from 12.6 using Cyclanilide with hand pruning to 25.4 using Atrimmec without pruning (Table 2). After twelve weeks, plants receiving the Atrimmec without pruning treatment produced significantly greater branch numbers than treatments with water, hand pruning, and Cyclanilide with or without hand pruning treatments, but not significantly different from plants receiving the Atrimmec with pruning treatment. The number of berries was greatly affected by whether or not plants were pruned (Table 2). 55% to 61% of branches on plants treated with Atrimmec with or without pruning were longer than 10 cm, indicating that a more compact plant may be produced over time. Pruning could remove fruiting wood that might have had berries. Plants in all three treatments without pruning had greater numbers of berries.

All plants in treatments without pruning were significantly taller than plants that were pruned (Table 3), as might be expected. Cyclanilide with and without pruning, water and hand-pruning controls, and Atrimmec-treated plants without pruning had greater width than plants treated with Atrimmec with pruning. Plants in all treatments with hand pruning had a lower growth index than those without pruning. The Atrimmec with pruning treatment produced a lower quality rating than water and hand pruning control treatments (Table 4).

Atrimmec increased branching, but was phytotoxic at 3800 ppm. Pruning was not effective at stimulating long branches and reduced berries. Atrimmec without pruning was effective at stimulating branches; however, phytoxicity resulted at the rates used in this study. Reducing the rate and maintaining or increasing the interval between applications may reduce phytotoxicity.

Literature Cited:

1. Holland, A.S., G.J. Keever, J.R. Kessler, Jr., and F. Dane. 2007. Multiple cyclanilide applications promote branching of woody ornamentals. J. Environ. Hort. 25:191-196.
2. Keever, G.J. and W.J. Foster. 1990. Chemically induced branching of woody landscape plants. J. Environ. Hort. 8:78-82.
3. Poston A., A. Fulcher, W. Dunwell, L. Dougherty, and R. Geneve. 2008. Fascination® increases growth of 'Rudy Haag' burning bush during container production. SNA Research Conference 53:501-505.

Table 1. Phytotoxicity on *Ilex verticillata* Winter Red® assessed at 1, 3, 6, and 12 weeks after treatment (WAT) using a scale of 0 (no phytotoxicity) to 10 (plant death).

Treatment	1 WAT	3 WAT	6 WAT	12 WAT
Cyclanilide with no hand pruning	1.17a[z]	1.17b	1.17b	0.92b
Cyclanilide with hand pruning	0.83a	0.58b	1.25b	0.75b
Atrimmec with no hand pruning	1.17a	3.25a	6.33a	2.83a
Atrimmec with hand pruning	1.17a	3.58a	6.75a	3.00a
Water spray only	0.42a	0.75b	0.50b	0.50b
Hand pruning only	0.50a	0.92b	0.00b	0.50b
ANOVA *P* value	0.0314	<0.0001	<0.0001	<0.0001

[z]Means followed by the same letter are not significantly different (Tukey's HSD; alpha = 0.05)

Table 2. Effect of plant growth regulators on growth of *Ilex verticillata* Winter Red® at 12 weeks after treatment.

Treatment	Total branches (no.)	Long (> 10 cm) branches (no.)	Berries (no.)
Cyclanilide with no hand pruning	18.75bc[z]	15.00a	183.17a
Cyclanilide with hand pruning	12.58d	9.42b	34.00b
Atrimmec with no hand pruning	25.42a	15.33a	144.00a
Atrimmec with hand pruning	23.25ab	12.75ab	38.25b
Water spray only	16.17dc	12.25ab	165.00a
Hand pruning only	13.92dc	9.67b	33.67b
ANOVA *P* value	<0.0001	0.0004	<0.0001

[z]Means followed by the same letter are not significantly different (Tukey's HSD; alpha = 0.05)

Table 3. Effect of plant growth regulators on growth of *Ilex verticillata* Winter Red® at 12 weeks after treatment.

Treatment	Height (cm)	Width (cm)	Growth index[z]
Cyclanilide with no hand pruning	99.29a[y]	53.46a	63.35a
Cyclanilide with hand pruning	70.25b	45.21ab	48.61b
Atrimmec with no hand pruning	98.83a	43.92ab	57.72a
Atrimmec with hand pruning	65.75b	34.71b	42.47b
Water spray only	94.79a	51.25a	60.83a
Hand pruning only	66.71b	44.75ab	46.86b
ANOVA *P* value	<0.0001	0.0002	<0.0001

[z]Growth index was calculated as (height + width)/2.
[y]Means followed by the same letter are not significantly different (Tukey's HSD; alpha = 0.05)

Table 4. Quality ratings of *Ilex verticillata* Winter Red® at 12 weeks after treatment.

Treatment	Quality rating[z]
Cyclanilide with no hand pruning	2.54ab[y]
Cyclanilide with hand pruning	2.92ab
Atrimmec with no hand pruning	2.00ab
Atrimmec with hand pruning	1.75b
Water spray only	3.21a
Hand pruning only	3.33a
ANOVA *P* value	0.0046

[z]A rating scale of 1 (least desirable plant having few branches or just one long branch, often curved at the top) to 5 (excellent, full, compact, and very desirable plant for the landscape) was used.
[y]Means followed by the same letter are not significantly different (Tukey's HSD; alpha = 0.05)

Fig. 1. Examples of quality ratings for *Ilex verticillata* Winter Red® plants rated at 12 weeks after treatment. A rating scale of 1(least desirable plant having few branches or just one long branch, often curved at the top) to 5 (excellent, full, compact, and very desirable plant for the landscape) was used.

Fig. 2. Plants of *Ilex verticillata* Winter Red® at 6 weeks after treatment. Treatments were: 1. Cyclanilide with no hand pruning, 2. Cyclanilide with hand pruning, 3. Atrimmec with no hand pruning, 4. Atrimmec with hand pruning; 5. water spray only, and 6. hand pruning only.