Growth Regulators

Gene Blythe
Section Editor and Moderator

Fascination® Increases Growth of 'Rudy Haag' Burning Bush during Container Production

Amy Poston[1], Amy Fulcher[1], Winston Dunwell[2], Leah Dougherty[1], and Robert Geneve[1]
[1]Department of Horticulture, University of Kentucky, Lexington, KY 40546
[2]Department of Horticulture, University of Kentucky Research and Education Center, Princeton, KY 42445

afulcher@uky.edu

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Significance to the Industry: 'Rudy Haag' is a nearly seedless cultivar of burning bush, making it suitable as an environmentally friendly alternative to other invasive cultivars. However, it is much slower growing than other currently used burning bush cultivars making it more costly to produce and limiting its prevalence in the nursery trade. A single application of Fascination® (a cytokinin/gibberellin growth regulator) increased plant size and stem number in container-grown 'Rudy Haag' plants. This effect was carried over into the second production year. After the second growing season, 'Compactus' plants were still larger than treated 'Rudy Haag' plants, but the increased size and branching in treated 'Rudy Haag' plants allowed them to reach a salable size after the second season in a three-gallon container.

Nature of the Work: Burning bush [*Euonymus alatus* (Thunb.) Sieb.] and its cultivars, especially 'Compactus,' are popular shrubs grown and sold by the nursery industry. Despite their popularity, these shrubs have been cited as escaping cultivation throughout much of the Eastern United States due to their abundant seed production and aggressive root systems allowing these plants to invade natural ecosystems and colonize disturbed areas (6). 'Rudy Haag' is a nearly seedless cultivar that could be utilized as an ecologically friendly alternative to other cultivars such as 'Compactus.'

Burning bush cultivars are considered slow growing during nursery production (8). Growth is typically limited to one growth flush in the spring (1). This is possibly due to deep bud rest that may require a cold treatment to induce breaking of terminal and lateral buds. 'Rudy Haag' has an even slower growth rate compared to other burning bush cultivars. It has been purported that 'Rudy Haag' has fewer branches and less extensive growth because it is more dwarf, therefore requiring more time in the nursery to produce a plant of salable size. The additional time required to produce 'Rudy Haag' has slowed its use by the nursery industry as an alternative to other burning bush cultivars.

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 the time of production. The use of cytokinin successfully increased bud development and, in some cases, bud break in woody plants such as some cultivars of rose (7), azalea (2), and spruce (4) by releasing buds from apical dominance. The combination of cytokinin and gibberellin has also been used to induce a second flush of growth on other slow-growing woody ornamentals with summer dormancy when applied to plants as a foliar spray in mid-June (5).

The objective of the current study was to evaluate the use of Fascination® (a cytokinin plus gibberellin growth regulator) on the growth of 'Compactus' and 'Rudy Haag' burning bush during nursery container production.

Liners of 'Compactus' and 'Rudy Haag' burning bush (Spring Meadow, Grand Rapids, MI) were potted on April 12, 2006 into one- or three-gallon Classic containers (Nursery Supplies, Inc., McMinnville, OR) with southern pine bark (Barky Beaver Professional Grow Mix, Barky Beaver Mulch & Soil Mix, Inc., Moss, TN), topdressed with 3-4 month Osmocote Plus 15-9-12 (Scotts Company, Marysville, OH) controlled-release fertilizer at a rate of 9 grams per gallon of container size, and trickle irrigated using one pressure-compensating line per gallon of container size.

Thirty plants were sprayed with water as a control or sprayed with 1500 ppm of Fascination® (1.8% 6-benzyladenine, 1.8% gibberellin 4+7; Valent, Walnut Creek, CA) to foliar runoff using a backpack sprayer on July 26, 2006. Growth index [(Ht + (Wdt1 + Wdt2)/2)/2] and branching were evaluated at the end of the growing season in 2006 and 2007 and after the spring flush in 2008.

Results and Discussion: 'Compactus' is commonly referred to as a dwarf burning bush cultivar, but 'Rudy Haag' plants were on average 30% smaller (Table 1). A single application of Fascination® had a dramatic effect on plant size and branching for 'Rudy Haag' burning bush plants grown in both one- and three-gallon containers and this effect carried over into the following season (Table 1; Figure 1). This is in contrast to Compactus' plants that were not significantly impacted by Fascination®. Over 50% of treated 'Rudy Haag' plants showed a second flush of growth within two weeks of Fascination® treatment. This translated into branch numbers that were comparable between Fascination®-treated 'Rudy Haag' and 'Compactus' plants evaluated either in 2006 or again in 2007. However, treated 'Rudy Haag' plants were still smaller than 'Compactus' in both years (Table 1; Figure 2).

A single application of Promalin (BA + $GA_{4/7}$) 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 (3). Boxwood, which has a similar growth pattern to burning bush, showed similar results for inducing growth after application of Promalin as a foliar spray in mid-June (5).

The use of larger containers only slightly increased growth in both burning bush cultivars (Table 1). However, the use of Fascination® induced a second flush of growth in 'Rudy Haag' that greatly increased its size during container production. This could alleviate some of the constraints on nursery production of 'Rudy Haag' as an ecologically friendly alternative to 'Compactus.'

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Table 1. Growth index and branching in *Euonymus alatus* 'Compactus' and 'Rudy Haag' plants grown in one and three gallon Classic containers treated with Fascination [1500 ppm] in July 2006 and evaluated at the end of the growing season in 2006 and 2007.

			2006			2007	
Cultivar	Container size	Plant growth regulator	Growth index	Branches (no.)	Branching (%)[z]	Growth index	Branches (no.)
'Compactus'	1 gallon	Water	23.2a[y]	21.8a	0	41.3a	63.8a
		Fascination	25.5a	22.8a	6.7	42.2a	66.8a
	3 gallon	Water	23.4a	22.0a	0	45.7a	69.8a
		Fascination	26.6	23.4a	3.3	42.2a	66.8a
'Rudy Haag'	1 gallon	Water	15.4b	15.3b	0	27.4b	39.9b
		Fascination	24.1a	27.3a	53.3	32.5a	60.7a
	3 gallon	Water	18.2b	17.0b	0	31.6b	48.6b
		Fascination	24.2a	27.9a	63.3	36.7a	78.2a

[z]Percentage branching indicates the percentage of plants in which branching resulted following application of Fascination®.
[y]Means within a column for each cultivar followed by the same letter were not different as indicated by a single degree of freedom contrast between water and Fascination at each container size.

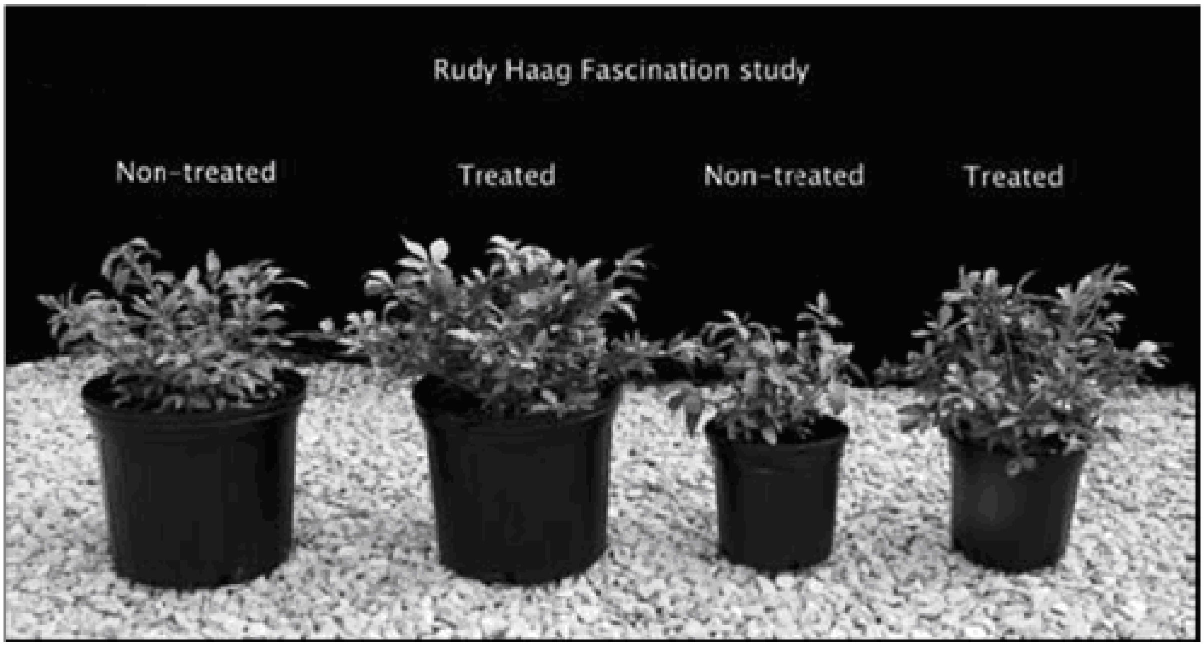

Figure 1. Increased shoot growth in ‘Rudy Haag’ plants treated with Fascination in July 2006 and photographed in September 2007.

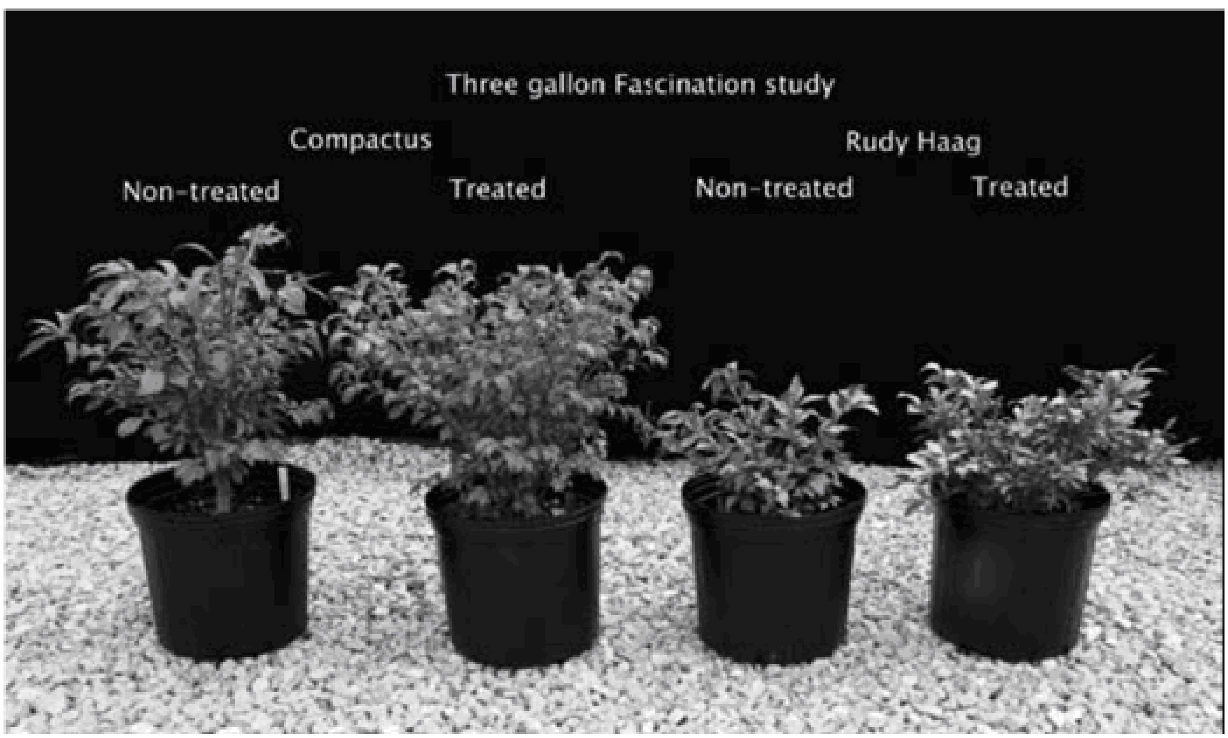

Figure 2. Comparison of ‘Compactus’ and ‘Rudy Haag’ plants treated with Fascination in July 2006 and photographed in September 2007.

Application Interval and Concentration Affect Plant Response to Cyclanilide

Z. Williamson[1], G.J. Keever[1], J.R. Kessler[1], and J.W. Olive[2]
[1]Auburn University, Department of Horticulture, Auburn, AL 36849
[2]Ornamental Horticulture Research Center, Mobile, AL 36608

willizo@auburn.edu

Index Words: Plant Growth Regulator, Auxin Transport Inhibitor, Branching

Significance to Industry: Cyclanilide (CYC) is an effective branching agent for 'Snow White' Indian hawthorn (*Rhaphiolepis indica* 'Snow White') and 'Sky Pencil' holly (*Ilex crenata* 'Sky Pencil') when three foliar applications of 50 or 100 ppm are made. However, the branching response is most persistent and end-of-season plant quality higher when CYC is applied every 6 weeks as opposed to intervals of one or three weeks. Indian hawthorn is more likely to be injured by multiple applications of 50 or 100 ppm CYC than 'Sky Pencil' holly, but injury is less severe and more transient with longer application intervals. Cyclanilide has the potential to substitute for mechanical pruning in production of these two woody ornamentals.

Nature of Work: Apical dominance, the suppression of lateral bud outgrowth by auxins produced in shoot apices (5), is broken when terminal shoots are removed. This process has practical implications in the production of most woody ornamental shrubs that are mechanically pruned to promote the dense canopy preferred by consumers. However, tissue removed during pruning increases the production time by at least two weeks per pruning (7). The exogenous application of cytokinins or plant growth regulators (PGRs) with cytokinin-like activity also can reduce apical dominance by counteracting auxins (1, 2, 3, 4, 5). Cyclanilide (CYC), a plant growth regulator (PGR) currently marketed in combination with ethephon as the cotton defoliant Finish, acts as an auxin transport inhibitor, temporarily interrupting apical dominance and allowing latent buds to mature and elongate (6). Studies indicate CYC has the potential to induce lateral branching without mechanical pruning during container nursery production (1, 2, 3, 4).

During initial testing on ornamentals, a single application of CYC stimulated branching in several nursery crops, including Indian hawthorn and 'Sky Pencil' holly, but branching response was limited to the flush following application (2). In subsequent studies that included 'Sky Pencil' holly and Indian hawthorn, three weekly or biweekly applications of 100 to 300 ppm CYC were more effective in stimulating branching than a single application (3). New shoot formation in 'Sky Pencil' holly increased 115% to 175%, plant width increased and plants were visibly more dense and compact than controls, and quality was higher. The greater width of CYC-treated plants was particularly desirable because it may reduce the number of liners per pot necessary to produce a marketable plant**.** However, new leaves on CYC-treated plants were noticeably more elongated than those on controls. Similarly, Indian hawthorn readily formed new shoots in response to three weekly or biweekly applications of 100 to 300 ppm CYC. However, transitory foliar injury that increased with CYC rate was severe enough to discourage weekly or biweekly applications at rates above 100 ppm (3). The objective of this study was to further investigate the interactive effect of CYC concentration and application interval on new shoot development and foliar injury on two species that differ in sensitivity to CYC. Our overall goal was to develop a production strategy using CYC as a season-long pruning agent while avoiding foliar injury that could impact marketability. Rooted stem cuttings of 'Snow White' Indian hawthorn and 'Sky Pencil' holly were potted into one-quart containers on November 27, 2006. Substrate consisted of 7:1 pine bark-sand mix amended (per yd^3) with 5 lb. dolomitic limestone, 1.5 lb. Micromax, and 16 lb. Polyon 17-6-12. Plants were grown in full sun with overhead irrigation applied twice daily. Plants were repotted and respaced as needed. Treatments, begun on May 17, 2007, consisted of three foliar applications of 50 or 100 ppm CYC at 1, 3, or 6 week intervals. An untreated control was included for comparison. CYC solutions included a non-ionic surfactant (Buffer X at 0.2%) and were applied using a CO_2 sprayer with a flat-spray nozzle at 20 psi in a volume of 2 qt./100 ft^2. Data collection included new shoot counts and growth measurements at 60 and 120 days after initial treatment (DAT). Treatments were arranged in a completely randomized design with 8 ('Sky Pencil' holly) or 10 ('Snow White' Indian hawthorn) single plant replicates. An analysis of variance was performed on data using SAS version 9.1.3 (SAS Institute, Cary, NC). Single degree of freedom orthogonal contrasts were used to test linear and quadratic treatment trends, and paired comparison contrasts were used to compare specific treatments at $P = 0.05$.

Results and Discussion: At 60 DAT there were 39, 26, and 29 new shoots on 'Snow White' Indian hawthorn treated with three applications of CYC at 1, 3, and 6 week intervals, respectively. These counts were all higher than the 18 on control plants and indicate an early benefit to a shorter application interval. Concentration had no effect on new shoot counts at 60 DAT (data not shown). At 120 DAT a different trend was evident. New shoots counts increased linearly with both 50 and 100 ppm CYC as application interval increased (Table 1), indicating that longer application intervals promoted shoot development over a longer period than the same number of applications made more frequently. New shoot counts on plants treated with both CYC concentrations at all application intervals were higher than those of the control, except with 100 ppm CYC applied weekly. Height of Indian hawthorn was minimally affected by treatments at 60 DAT (data not shown) or at 120 DAT (Table 1). Transient foliar discoloration and leaf cupping occurred on Indian hawthorn receiving either CYC concentration, but decreased as application interval increased. At the end of the growing season, plant quality rating increased as application interval increased, regardless of CYC concentration, and was higher than that of the control in all CYC treatments (data not shown).

New shoot counts on 'Sky Pencil' holly were not affected by treatments at 60 DAT (data not shown); however, at 120 DAT new shoot counts increased as both CYC concentration and application interval increased and were higher than those of the control, regardless of concentration or application interval (Table 2). Height of 'Sky Pencil' holly at 60 DAT was reduced by CYC application intervals of 1 (22.4 cm), 3 (18.7

cm), and 6 weeks (21.0 cm) compared to that of the control (27.9 cm). At 120 DAT there was a linear decrease in plant height as application interval increased (1 wk: 54.8 cm, 3 wk: 51.6 cm, 6 wk: 49.1 cm). However, only height of plants treated at a 6 week interval were less than the 58.5 cm mean of the controls. Plant width increased linearly at 60 DAT with increasing application interval (1 wk: 6.7 cm, 3 wk: 7.9 cm, 6 wk: 7.3 cm). Widths of plants treated at 3 or 6 week intervals were greater than that of the control (6.1 cm). CYC similarly promoted increased plant width at 120 DAT with the greatest effect from the higher concentration and longer application intervals. ‘Sky Pencil’ holly was not injured by any CYC treatment, possibly due to the lower concentrations applied compared to earlier work (4). Plant quality rating increased linearly as application interval increased, regardless of concentration, and was higher for plants in all CYC treatments than for controls. These higher quality ratings reflect fuller, more compact, and wider plants treated with CYC.

Results of this study indicate that a CYC application interval of 6 weeks is more effective than shorter intervals in promoting extended new shoot development and higher quality in ‘Snow White’ Indian hawthorn and ‘Sky Pencil’ holly. Longer application intervals, especially of 100 ppm CYC, also resulted in wider ‘Sky Pencil’ holly, a desirable characteristic in marketing this often spindly cultivar. CYC concentration had much less effect on growth of these two species than application interval, and no effect in many cases.

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Table 1. CYC application interval and concentration effects on height and new shoot counts of ‘Snow White’ Indian hawthorn and width of ‘Sky Pencil’ holly.[z]

Indian hawthorn height (cm) at 120 days after initial treatment (DAT)			
	Concentration (ppm)		
Application interval (wk)	0	50	100
1	22.1	22.0	21.8*[y]
3		21.7*	24.7
6		22.5	22.1
Significance[x]		Q*	NS
Indian hawthorn shoot counts at 120 DAT			
	Concentration (ppm)		
Application interval (wk)	0	50	100
1	28	34*[x]	33
3		48*	45+ [w]*
6		55*	55*
Significance		L***	L***
Holly width at 120 DAT			
	Concentration (ppm)		
Application interval (wk)	0	50	100
1	11.5	11.9	12.7*
3		11.1	13.8+*
6		12.6*	14.0+*
Significance		Q**	L*

[z]An application interval x concentration interaction affected all reported responses ($\alpha \leq 0.05$).
[y]Means followed by an asterisk are significantly different from the control ($\alpha \leq 0.05$).
[x]Response within rate exhibited a nonsignificant (NS) or a significant linear (L) or quadratic (Q) trend at $\alpha \leq 0.05$ (*), $\alpha = 0.01$ (**), or $\alpha = 0.001$ (***).
[w]Means followed by a '+' sign are significantly different from the mean for 50 ppm treatment within the same application interval.

Table 2. CYC application interval and concentration effects on new shoot counts in ‘Sky Pencil’ holly.

Holly shoot count at 120 DAT ^{z}			
Concentration (ppm)	Shoot count	Application interval	Shoot count
0	28	1	37*^{y}
50	48	3	47*
100	44	6	55*
Significance^{x}	L***		L***

^{z}Days after initial treatment.
^{y}Application interval means followed by an asterisk are significantly different from the mean of the control, $\alpha \leq 0.05$.
^{x}Only main effects significant; linear (L) response at $\alpha = 0.001$ (***).

Benzyladenine and Cyclanilide Affect Shoot Production and Flowering of *Coreopsis verticillata* 'Moonbeam'

M. E. Farris, G. J. Keever, J. R. Kessler, and J.W. Olive
Auburn University, Dept. of Horticulture, Auburn, AL 36849

farrime@auburn.edu

Index Words: Apical Dominance, Plant Growth Regulators, Cytokinins, Cyclanilide, Benzyladenine, Drench Application, Spray Application, *Coreopsis verticillata* 'Moonbeam'

Significance to Industry: A single foliar spray or basal drench of 250 to 2000 ppm benzyladenine (BA) can greatly enhance vegetative and reproductive shoots in 'Moonbeam' coreopsis resulting in the formation of more flower buds. However, because of temporary foliar chlorosis and a significant delay in flowering that occurs with use of 1000 or 2000 ppm BA, BA should not be applied at rates above 500 ppm. Cyclanilide (CYC) at 25 to 100 ppm stimulated 'Moonbeam' coreopsis to produce more flower buds, but not reproductive or vegetative shoots, than controls, but fewer than BA. Of the rates tested, 25 ppm CYC resulted in the most flower buds without any delay in flowering, although all rates resulted in some twisting of shoots and a more horizontal growth habit. Both BA and CYC have potential to enhance flowering of 'Moonbeam' coreopsis.

Nature of Work: *Coreopsis verticillata* 'Moonbeam' ('Moonbeam' coreopsis), the 1992 Perennial Plant of the Year (9), bears muted yellow flowers on terminal and axillary shoots from late spring through summer. Producing saleable plants of 'Moonbeam' coreopsis for the peak spring market requires propagation from cuttings or division, although tip cuttings are more widely used (8). Tip cuttings are commonly harvested from stock plants from fall through spring or any time flowers are not present. Following rooting and repotting, vegetative plants are typically pruned multiple times to increase the number of potential flowering shoots and promote compactness and fullness.

Cytokinins are naturally occurring plant hormones and synthetic plant growth regulators that function in overcoming apical dominance and in promoting lateral bud outgrowth (7). Exogenous foliar or drench applications of the cytokinin benzyladenine (BA) have promoted new shoot development in herbaceous and woody landscape plants (4, 5, 6). More recently, the bioregulator cyclanilide (CYC) promoted lateral shoot development of apple and cherry trees (1, 2) and several woody landscape species and cultivars (3). The objective of this study was to determine the effects of BA and CYC applied as foliar sprays or substrate drenches on the growth and flowering of 'Moonbeam' coreopsis.

Non-flowering terminal shoots of 'Moonbeam' coreopsis were stuck in 288-cell flats containing Fafard Germination Mix on November 8, 2007. Shoots were rooted under intermittent mist operating for 5 seconds every 5 minutes from 8:00 AM to 5:00 PM in a shaded, glass-covered greenhouse. Rooted cuttings were transplanted into 4-in plastic pots containing Fafard 3B potting medium on November 25, 2007. Plants were spaced pot-to-pot in an unshaded, twin-wall, polycarbonate-covered greenhouse with a heating set point of 65°F and a ventilation set point of 78°F under natural photoperiod.

On January 15, 2008, 136 unbranched ‘Moonbeam’ coreopsis, 1 to 1.5 cm in height, were selected for uniformity. Plants chosen had roots visible at the bottom and sides of the container medium. The following treatments were applied on the same day: an untreated control; 25, 50, 75, or 100 ppm CYC; or 250, 500, 1000, or 2000 ppm BA; with BA and CYC each applied as a foliar spray or as a medium drench (17 treatments). Spray treatments included a non-ionic surfactant, Buffer-X at 0.2%, and were applied at 2 qt/100 ft^2 using a CO_2 sprayer with a flat spray nozzle set at 138 kPa. Drench treatments were applied at 2 oz/pot to the medium surface. Night interrupted lighting (NIL) from 10:00 PM to 2:00 AM was begun on January 20, 2008.

Data collection included basal shoot count and basal shoot length (mean of 3 longest basal shoots) at 3 weeks after treatment (WAT), days to first flower, days to full flower (date when 5 flowers were fully open), and flower bud, reproductive shoot, and vegetative shoot counts at 5 open flowers. Phytotoxicity, as a percentage of foliage exhibiting chlorosis, was rated at 4 WAT using a 1 to 5 scale (1 = 0%, 2 = 1-25%, 3 = 26-50%, 4 = 51-75%, and 5 = 76-100%). An analysis of variance was performed on data using SAS version 9.1.3 (SAS Institute, Cary, NC). Single degree of freedom orthogonal contrasts were used to test linear and quadratic treatment trends, and paired comparison contrasts were used to compare application methods and PGRs at P = 0.05.

Results and Discussion: Shoot formation was affected by plant growth regulator (PGR) type, application method, and rate. At 3 WAT, plants treated with BA produced 33% more basal shoots that those treated with CYC (Table 1.). Within the group of plants treated with BA, those treated with a drench produced 42% more basal shoots and shoots that were 37% longer than those treated with a spray application. In contrast, plants treated with a CYC spray produced 45% more basal shoots that were 20% longer than those treated with a CYC foliar spray. Basal shoot number responded quadratically to increasing BA rate, with the highest counts in plants treated with 500 or 1000 ppm BA. Basal shoot counts decreased linearly as CYC rate increased. Basal shoot length also decreased linearly as BA and CYC rates increased. Plants treated with both CYC and BA were shorter than controls throughout the experiment. At 4 WAT, phytotoxicity, in the form of foliar chlorosis, was evident in plants treated with the two highest rates of BA, regardless of application method. However, the chlorosis was generally transient and not evident in most plants at the end of the experiment. At 5 WAT, plants treated with BA also had a more uniform and fuller appearance than controls, while plants treated with CYC had begun to form twisted, horizontally growing shoots which persisted throughout the experiment.

Days to first flower was altered by BA, but not by CYC. Plants treated with BA took an average of 5 more days to reach first flower than those treated with CYC. A drench application of BA caused plants to reach first flower 3 days later than those treated with a spray application. Time to first flower increased linearly with increasing rate of BA.

Plants that received an application of 2000 ppm BA reached first flower 12 days later than controls. Days to full flower were similarly delayed by BA. CYC delayed time to full flower by 1 to 4 days.

BA resulted in 22%, 134%, and 182% greater flower bud, reproductive shoot, and vegetative shoot counts, respectively, than did CYC at full flower. However, application method had no effect on these variables, regardless of PGR. Flower bud counts increased linearly with increasing rates of BA. Plants treated with 250, 500, 1000 and 2000 ppm BA produced 17%, 50%, 60%, and 63% more flower buds, respectively, than did controls. Reproductive shoot counts for plants treated with BA were 134% greater than those treated with CYC. When compared with the control, plants treated with 250, 500, 1000, and 2000 ppm BA had 77%, 148%, 169%, and 207% more reproductive shoots, respectively. Vegetative shoot counts followed a trend similar to that of reproductive shoot counts.

A foliar spray or basal drench of 250 to 2000 ppm promoted vegetative and reproductive shoot development in ‘Moonbeam’ coreopsis resulting in the formation of more flower buds. This response was enhanced by higher rates of BA, although 1000 and 2000 ppm BA resulted in temporary chlorosis and a significant delay in flowering, and was unaffected by application method. BA at 500 ppm stimulated ‘Moonbeam’ coreopsis to produce 148% more reproductive shoots than controls and time to 5 flowers was delayed by only 6 days. CYC promoted increased flower bud production, but not an increase in reproductive or vegetative shoot formation. Shoots on CYC-treated plants also were visibly twisted and more horizontal than those on controls.

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Table 1. Effect of CYC and BA rate and application method on vegetative growth and flowering of 'Moonbeam' coreopsis.[z]

PGR	Rate (ppm)	3 WAT[y] Basal shoots (no.)	3 WAT[y] Basal shoot length (cm)[x]	Days to first flower	Days to 5 flowers	At 5 open flowers Flower buds (no.)	At 5 open flowers Reproductive shoots (no.)	At 5 open flowers Vegetative shoots (no.)
CYC	0[w]	6.3	7.9	59	63	92.1	15.3	5.5
	25	6.4	6.2	59	64	126.1	15.9	4.4
	50	5.6	4.6	59	64	111.6	17.6	5.6
	75	4.8	4.7	59	66	112.1	17.0	5.1
	100	4.9	4.0	62	67	107.7	15.1	5.4
Significance[w]		L*	L***	NS	L **	Q **	NS	NS
BA	0	6.3	7.9	59	62	92.1	15.3	5.5
	250	6.8	6.3	61	65	108.2	27.1	8.8
	500	7.7	4.9	64	69	137.8	38.0	14.8
	1000	7.0	4.5	65	70	147.2	41.1	15.6
	2000	5.1	3.4	71	78	150.3	47.0	18.0
Significance		Q**	L ***	L ***	L ***	L ***	L***	L ***
	Application method							
CYC	Spray	6.4	5.3	60	65	108.7	16.4	5.8
	Drench	4.4 ***[v]	4.4 *	59 NS	66 NS	113.3 NS	16.4 NS	4.4 NS
BA	Spray	3.8	5.9	64	68	136.3	39.8	14.0
	Drench	5.4 ***	3.7 ***	67 ***	72 **	135.5 NS	36.9 NS	14.6 NS
CYC		4.9	4.9	60	65	111.0	16.4	5.1
BA		6.5 **	4.8 NS	65 ***	70 ***	135.9 ***	38.4 ***	14.3 ***

[z] There were no method by rate interactions for any parameter measured; hence, only main effects are reported.
[y] Weeks after treatment. Plants were treated on January 15, 2008.
[x] Basal shoot length is the mean of the 3 longest basal shoots of each plant.
[w] Nonsignificant (NS) or significant linear (L) or quadratic (Q) trends at P = 0.05 (*), P = 0.01 (**), P = 0.001 (***). Control included in trend analysis.
[v] Nonsignificant (NS) or a significant difference between application methods or between PGRs at P = 0.05 (*), P = 0.01 (**), P = 0.001 (***).

Plant Growth Regulation of Ornamental Grasses

Brian W. Trader and Mengmeng Gu
Mississippi State University, Dept. of Plant and Soil Sciences, MS State, MS 39762

btrader@pss.msstate.edu

Index Words: Primo MAXX™; Trinexapac-ethyl; *Calamagrostis*; *Cortaderia*; *Festuca*; *Miscanthus*; *Mulhenbergia*; *Pennisetum*

Significance to Industry: Ornamental grasses are fast growing and heavy feeding perennials that often consume large amounts of space during nursery production. Managing the rate of growth 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 treated with trinexapac-ethyl (Primo MAXX™) at 0, 15, 25, 35 and 45 oz/acre one week after transplanting. Early applications at 35 and 45 oz/acre were more effective in reducing height in some of the grass species. All grasses responded to Primo applications. Additional research is needed on timing and application rate of Primo on various ornamental grasses to determine efficacy.

Nature of Work: Ornamental grasses have become increasingly popular for use in American landscapes (1). Many genera of ornamental grasses perform well in heat and humidity under full sun conditions with the ability to survive through periods of drought. Variation in color, size, texture, and flowers enables grasses to add contrast to a landscape through different seasons of the year. The popularity of these grasses has been discussed previously (2) and the number of species available and their use has been documented (3).
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 to manage the height of their grass crops. Previous research has shown the potential for plant growth regulation of ornamental grasses during production (4).

The objective of this study was to determine the effect of timing and application rate of trinexapac-ethyl on phytotoxicity, height, and tiller number on certain ornamental grasses. Liners of *Calamagrostis* x *acutiflora* 'Karl Foerster', *Cortaderia selloana*, *Festuca glauca* 'Elijah Blue', *Miscanthus sinensis* 'Gracillimus', *Muhlenbergia capillaris*, and *Pennisetum setaceum* 'Rubrum' were received in May 2007 and potted into a mix containing 75% bark fines and 25% Pro Mix BX. Plants were top-dressed with 3-4 month Osmocote controlled-release fertilizer at transplanting and allowed to establish for approximately three weeks. Actively growing grasses were treated with trinexapac-ethyl (Primo™) at 0, 15, 25, 35 and 45 oz/acre using a CO_2 pressurized backpack sprayer on June 5, 2007; a second application was made four weeks later on July 5, 2007. Plants were grown outside on nursery fabric and were watered daily by hand. Data on plant injury and height was collected 0, 7, 14, and 28 days after treatment.

Injury ratings were determined visually on a scale of 0 to 10, where 0 = no injury and 10 = plant death. Treatments were arranged by species in a completely randomized design with three plants per rep in four 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 spray treatments on the species tested at any rate at either time of application. Height and tiller number for the six species of ornamental grasses four weeks after first application are presented in Table 1. There were significant decreases in height of all grass species using Primo in comparison with nontreated plants (Table 1). Although safe on *Festuca glauca* 'Elijah Blue', Primo applications at 45 oz/acre significantly reduced both height and width of plants. Primo applied at 35 or 45 oz/acre was most effective at reducing height on most species. Application of Primo did not significantly increase tiller production of the species tested (Table 1). The second application of Primo did not significantly decrease height in either grass species and there was no effect on tillering (data not shown).

Future research will evaluate the same rates of Primo applied to various grass species earlier in the growing season. It is believed that the treatments may have more of an effect on height control under cooler weather conditions. Additional research will evaluate liner drenches prior to transplanting as well. From our preliminary research we believe that Primo may be an effective growth regulator for height management in ornamental grass production.

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Table 1. Effect of Primo MAXX™ applied as a spray to three-week-old transplanted liners of six species of ornamental grasses at four weeks after treatment.

	Calamagrostis		*Cortaderia*		*Festuca*		*Miscanthus*		*Muhlenbergia*		*Pennisetum*	
Rate of Primo MAXX™	Height (cm)	Tillers (no.)	Height (cm)	Tillers (no.)	Height (cm)	Width (cm)	Height (cm)	Tillers (no.)	Height (cm)	Tillers (no.)	Height (cm)	Tillers (no.)
0 oz/ acre	80.7 a[z]	23.0 a	79.2 a	9.8 a	16.1 ab	19.3 ab	58.1 a	22.4 a	66.2 ab	16.7 a	56.9 a	16.4 a
15 oz/ acre	74.6 ab	18.9 b	65.6 b	12.7 a	17.5 a	21.9 a	51.3 ab	19.3 bc	63.4 abc	16.3 ab	46.0 bc	18.7 a
25 oz/ acre	80.6 a	19.4 b	76.8 ab	12.3 a	14.5 ab	15.6 bc	45.4 b	19.0 bc	66.8 a	16.4 ab	50.7 b	18.2 a
35 oz/ acre	68.4 b	19.3 b	73.8 ab	12.0 a	15.3 ab	17.9 abc	57.4 a	18.0 c	61.3 bc	15.0 b	43.2 c	16.9 a
45 oz/ acre	74.5 ab	16.8 b	75.3 ab	11.2 a	12.5 b	13.2 c	46.9 b	20.2 b	60.2 c	16.7 a	50.2 b	17.3 a

[z]Means followed by the same letter within a column are not significantly different at $P = 0.05$ according to Fisher's Protected LSD.

Benzyladenine Foliar Sprays Increase Offsets on *Sempervivum* and *Echeveria*

Dennis Carey, Brian Whipker, Ingram McCall, and Wayne Buhler
North Carolina State University, Department of Horticulture Science,
Raleigh, NC 27695-7609

decarey@mindspring.com

Index Words: BA, BAP, 6-BA, 6-Benzylaminopurine, N6-Benzyladenine, Configure, Cytokinin, *Echeveria setosa*, Hens and Chicks, Firecracker Plant, Plant Growth Regulator, PGR, *Sempervivum*.

Significance to Industry: *Sempervivum* (hens and chicks) and *Echeveria setosa* (firecracker plant) are small succulent plants that are slow to grow and slow to produce offsets for propagation. Configure (2% benzyladenine; Fine Americas, Inc., Walnut Creek, CA), a cytokinin-based plant growth regulator (PGR), was applied to *Sempervivum* and *Echeveria* plants in order to determine its efficacy as a branching agent. Single foliar spray doses of Configure at 50, 100, 200, and 400 ppm were applied 22 days after potting and the offsets were counted 72 days after potting. Configure increased the number of offsets of the three taxa that were tested. Configure can be used in the production of *Sempervivum* and *Echeveria* to produce a fuller plant for sale or to produce more offsets for use in propagation.

Nature of Work: *Sempervivum* and *Echeveria* are small succulent plants that are popular in the horticulture trade for containers, green roofs, and xeriscape gardens. These plants are considered to be retail ready when the mother plant or the mother plant plus the surrounding offsets have grown to fill the pot. These plants are propagated via offsets that form at the end of short stolons. *Sempervivum* and *Echeveria setosa* are slow to grow to retail size and are slow to form offsets. Cytokinins, such as benzyladenine, are known to increase cell division and favor shoot formation. Prior experiments have shown that succulent plants such as sedum (1) and holiday cactus (2,3,4,5) exhibited increased branching and flowering with the application of benzyladenine-based chemicals. Two cultivars of *Sempervivum* (‘Red Heart’ and ‘Green Wheel’) and one species of *Echeveria* (*E. setosa*) were used. On March 8, 2007, plants were placed in 11-cm round [575 ml volume (4 inch)] pots in a peat-based media (Berger BM6; Berger Peat Moss, St. Modeste, Quebec, Canada) containing 75% to 80% Canadian sphagnum peat and 20% to 25% perlite. Plants were irrigated with clear water or with 150 ppm N from Excel® 15-5-15 Cal-Mag (15N-2.1P-12.5K; Scotts, Marysville, OH). Greenhouse day/night temperature set points were 24/18°C (75/65°F) and plants were grown under natural day length. On March 30, plants were sprayed with Configure, a benzyladenine-based plant growth regulator (PGR), at rates of 50, 100, 200, or 400 ppm. A nontreated control was also included. The experiment was a completely randomized design with six single plant replications. On May 20, 2007, the offsets were counted. On July 5, 2007, flower stalks on the *Echeveria setosa* plants were counted. Data were tested by analysis of variance using the linear model procedure (PROC GLM) of SAS (SAS Institute, Cary, NC). Means were separated by pair-wise testing using Fisher’s LSD at $P < 0.05$.

Next, the *Sempervivum* offsets were rooted to determine if treatment of the parent plant affected rooting of the offset. On July 12, 2007, mid-sized offsets were harvested off of parent plants from each original treatment level and placed into 1203 cell packs. They were grown under similar conditions as the parent plants. The experiment was a completely randomized design with six single plant replications. On September 27, 2007 the rooting success of the offsets was recorded. Data were tested by analysis of variance using the linear model procedure (PROC GLM) of SAS.

Results and Discussion: All three plant types responded to increasing levels of Configure by producing more offsets (Table 1). The effective rates were 200-400 ppm. In general, the more offsets that were produced, the smaller they were. In addition, *Echeveria setosa* plants produced more flower stalks in response to higher rates of Configure. *Sempervivum* 'Red Heart' plants sprayed with 200 and 400 ppm Configure produced an average of 24% and 71% more offsets, respectively, than the control plants. *Sempervivum* 'Green Wheel' plants sprayed with 200 or 400 ppm Configure produced an average of 180% and 324% more offsets, respectively, than the control plants. *Echeveria setosa* plants sprayed with 200 and 400 ppm Configure produced 144% and 222% more offsets, respectively, than the control plants. Additionally, *Echeveria setosa* plants sprayed with Configure rates of 200 ppm or higher produced more flower stalks than did control plants (Table 2). When sprayed with 200 or 400 ppm Configure, plants produced 600% and 700% more flower stalks, respectively, on average than the control plants.

The treatment level of the parent plant did not affect the rooting ability or root quality of the offsets. As the number of offsets increased, the offset size became smaller. Growers typically want the largest possible offset, so there is a balancing act between producing more offsets and the size of the offsets. Given the high level of activity of Configure in these experiments, it is clear that Configure can be used to increase the productivity of stock plants of *Sempervivum* and *Echeveria setosa*. If a grower is growing these plants for sale, then the recommended rate of Configure is 400 ppm so that the plant produces the largest number of offsets and the fullest plant. However, if the plants are being used as stock plants, then the recommended rate of Configure is 200 ppm which strikes a balance between the increase in offset production and the reduction in offset size. If growers want to harvest offsets over a period of time instead of all at once, they can treat stock plants with 400 ppm Configure and then harvest only the largest offsets over a period of weeks.

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Table 1. The effects of Configure spray rate on the number of offsets produced by *Sempervivum* 'Red Heart', *Sempervivum* 'Green Wheel', and *Echeveria setosa*.

	Offsets produced (no.)		
Configure Rate	*S.* 'Red Heart'	*S.* 'Green Wheel'	*E. setosa*
Control (0 ppm)	12.83 b	7.50 c	1.50 b
50 ppm	14.60 b	7.17 c	1.67 b
100 ppm	15.50 b	9.50 c	1.50 b
200 ppm	16.00 b	21.00 b	3.67 a
400 ppm	22.00 a	31.83 a	4.83 a

Means followed by different letters are significantly different at the alpha = 5% level using Fisher's LSD

Table 2. The effects of Configure spray rate on the number of flower stalks present on *Echeveria setosa* on July 12.

Configure rate	Flower stalks (no.)
Control (0 ppm)	0.17 b
50 ppm	0.00 b
100 ppm	0.33 b
200 ppm	1.17 a
400 ppm	1.33 a

Means followed by different letters are significantly different at the alpha = 5% level using Fisher's LSD.

Bark Penetrating Surfactant and Ethephon did not Control Leafy Mistletoe in Spring

Mengmeng Gu, Shen Ma, and Brian W. Trader
Mississippi State University, Dept. of Plant and Soil Sciences, MS State, MS 39762

mgu@pss.msstate.edu

Index Words: Florel®, Pentra-Bark®, Oak, Quercus

Significance to Industry: Oak trees infested by leafy mistletoe were treated with 12 fl. oz (355 ml) or 64 fl. oz (1.9 L) bark penetrating surfactant per 100 gal. (378.5 L) spray mix with 0, 0.54% a.i. (5,400 ppm) or 2.0% a.i. (20,000ppm) ethephon (Florel) at the end of March and the beginning of April, 2008. No abscission of leafy mistletoe was observed at the rates of surfactant and ethephon combination. Different rates of surfactant and ethephon combination and application time will need to be investigated to provide effective shoot reduction of leafy mistletoe.

Nature of Work: Leafy mistletoes are evergreen parasitic plants commonly seen on oak trees in the southern landscape. They are easily observed on deciduous trees in winter after leaves fall from the trees. Leafy mistletoes divert water and nutrients from the host tree to support their own growth and development. Depending on the level of infestation, the host tree may suffer from reduced tree vigor and increased susceptibility to insects and diseases (1). There have been various attempts to eliminate leafy mistletoe using ethephon marketed under the name Florel®. The label on Florel Brand Fruit Eliminator as a foliar spray on ornamental deciduous trees for removal of leafy mistletoe shoots recommended applications after fall leaf drop through midwinter at the rate of 0.54% a.i. (5,400 ppm). Spray application at rates of 0.21-2.0% a.i (2,100-20,000 ppm) have resulted in defoliation of leafy mistletoe at levels of 33-100% (1), while the growth of the infesting mistletoe was not affected when 0.03 fl. oz (1 ml) of ethephon was injected into 0.04” (6 mm)-diameter holes drilled 1” (2.5 cm) deep into the trunk of a large limb (2). 10% a.i. ethephon applied to freshly cut mistletoe stubs could greatly reduce mistletoe re-growth and provide over 90% control after two growing seasons (1).

However, problems come along with foliar spray application to large landscape trees, including the requirement of special spraying equipment for complete coverage of the tree canopy and the possibility of chemical drift to other plants. Also, application on freshly cut stubs requires special equipment to reach and apply chemical solutions to mistletoes on trees.

Pentra-bark® is a new bark penetrating surfactant designed for use in certain agricultural and horticultural uses where a nonionic surfactant is recommended. It could be used to aid penetration of various categories of chemicals through the bark including fertilizers, nutrients, insecticides, fungicides, herbicides, defoliants and desiccants. The suggested rates for use with chemicals range from 4 to 64 fl. oz per 100 gal. Pentra-bark has shown consistently effective results for bark application of phosphite in suppressing bark colonization by the sudden oak death pathogen without causing phytotoxicity in coast live oak compared with foliar application of phosphites (3).

The objective of this study was to evaluate the possibility of using bark penetrating surfactant to deliver ethephon via basal bark spray application to control leafy mistletoe in landscape trees. The number of leafy mistletoe on oak trees (*Quercus spp*.) on the campus of Mississippi State University were surveyed in the winter of 2007 after leaves fell off, resulting in a count of 66 trees (circumference ranging from 2'9"/0.8 m to 17'5"/5.3 m) with the number of leafy mistletoe ranging from 2 to 120. Trees were randomly assigned to bark spray applications with one of the following rates on March 21, April 2, or April 3, 2008: (1) 12 fl. oz (355 ml) bark penetrating surfactant per 100 gal. (378.5 L) water; (2) 64 fl. oz (1.9 L) bark penetrating surfactant per 100 gal. (378.5 L) water; (3) 12 fl. oz (355 ml) bark penetrating surfactant per 100 gal. (378.5 L) spray mix with 0.54% a.i. (5,400 ppm) ethephon; (4) 12 fl. oz (355 ml) bark penetrating surfactant per 100 gal. (378.5 L) spray mix with 2.0% a.i. (20,000ppm) ethephon; (5) 64 fl. oz (1.9 L) bark penetrating surfactant per 100 gal. (378.5 L) spray mix with 0.54% a.i. (5,400 ppm) ethephon; or (6) 64 fl. oz (1.9 L) bark penetrating surfactant per 100 gal. (378.5 L) spray mix with 2.0% a.i. (20,000ppm) ethephon. The bark spray application was conducted on March 21, April 2, or April 3, 2008 when the minimum daily temperatures were above 40 ºF (4.4 ºC) for at least 5 days since it was noted that ethephon application with temperature below 40 ºF (4.4 ºC) were ineffective (3). The trunk from the base to breast height was thoroughly sprayed with the solution to the point of runoff. Defoliation of leafy mistletoe was observed 30 days after application of ethephon (2). The experiment was a completely randomized design with the rate combination of the bark penetrating surfactant and ethephon as the main factor.

Results and Discussion: No defoliation of leafy mistletoe was observed 30 days after the application of any concentration of bark penetrating surfactant and ethephon combination. It was noted that foliar spray application of ethephon after mistletoe growth has begun (March-April) was ineffective (1), and this study confirmed that after mistletoe started spring growth application of ethephon was not effective. Higher rates of surfactant and ethephon combination and application time (in the fall) will need to be investigated for effective shoot reduction of leafy mistletoe through bark spray application.

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