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Cyclanilide Promotes Lateral Branching in Nursery Production of Woody Landscape Species[1]

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Abstract

During nursery production of landscape trees and shrubs it is desirable to promote the development of well-branched plants to achieve a uniform, full appearance. Branching may be promoted with multiple prunings but this is labor-intensive and expensive. In this study, spray applications of the bioregulator, cyclanilide (CYC), were evaluated for promotion of lateral branching on several container-grown landscape species. CYC spray concentrations of 0, 54, 106, and 212 ppm resulted in a linear increase in new lateral shoots for 'Muskogee' crape myrtle, 'Pinkie' and Eleanor Taber™ Indian hawthorn, and 'Girard Rose' azalea, and a quadratic increase in lateral shoots for 'Compacta' inkberry holly. Treatments to crape myrtle also caused a delay in flowering. CYC applications to Fraser photinia caused phytotoxic symptoms of leaf yellowing, blotching and curling, and increased susceptibility to entomosporium leaf spot.

Index words: plant growth regulator, woody ornamentals, nursery production.

Species used in this study: 'Muskogee' crape myrtle (*Lagerstroemia indica* L. ×*fauriei* Koehne 'Muskogee'), 'Compacta' inkberry holly (*Ilex glabra* (L.) A. Gray 'Compacta'), Fraser photinia (*Photinia* ×*fraseri* Dress), 'Pinkie' Indian hawthorn (*Rhaphiolepis indica* (L.) Lindl. 'Pinkie'), Eleanor Taber™ Indian hawthorn (*Rhaphiolepis indica* (L.) Lindl.), Japanese black pine (*Pinus thunbergii* Parl.), 'Girard Rose' hybrid azalea (*Rhododendron* × 'Girard Rose').

Chemicals used in this study: cyclanilide, 1-(2,4-dichlorophenylaminocarbonyl)-cyclopropane carboxylic acid.

Significance to the Industry

Plant growth regulators (PGRs) have the potential to substitute or supplement mechanical pruning of woody landscape plants to promote branching and the development of a compact, full appearance. Cyclanilide (CYC) is an experimental bioregulator that may be more effective for this purpose than currently available PGRs. In this study, application of foliar sprays in the range of 54 to 212 ppm promoted lateral branching of 'Muscogee' crape myrtle, 'Compacta' inkberry holly, 'Pinkie' and Eleanor Taber™ Indian hawthorn, and 'Girard Rose' azalea. For these plants lateral branching was promoted with little or no reduction in plant size. However, application to Fraser photinia resulted in phytotoxic symptoms of leaf yellowing, blotching, and curling, and an increased susceptibility to entomosporium leaf spot. CYC should not be applied to Fraser photinia at the rates evaluated in this study.

Introduction

During nursery production of many woody landscape plants, several prunings are needed to promote branching in order to produce well-formed plants with a dense, compact framework. However, pruning is labor-intensive, time-consuming, expensive, and can increase production time. Spray applications of the synthetic cytokinin, benzyladenine (BA) have promoted lateral branching on some woody landscape species including Indian hawthorn (13, 14), and nandina (11). However, BA can cause foliar injury, depending upon species and application timing (15) and it is not currently labeled for this purpose. Ethephon (Pistill, Monterey Lawn and Garden Products, Inc., Fresno, CA), a product that converts to ethylene upon entering the plant, is labeled for increasing lateral branching of several floricultural crops. It has promoted branching on azalea (16), crape myrtle (12), rose (8), and several herbaceous perennials (9) but its effectiveness in inducing lateral shoot development for most woody species appears to be limited. Dikegulac sodium (Atrimmec, PBI/Gordon, Kansas City, MO) is labeled for growth retardation, inhibition of apical dominance and promotion of lateral branching on many greenhouse, nursery, and landscape species. However, its growth retardation effect (1, 2, 4, 7) is not always desirable for nursery production and it can cause a temporary leaf yellowing in some species (2). More recently, the bioregulator cyclanilide (CYC, Bayer Environmental Science, Research Triangle Park, NC) was found to be effective in stimulating the formation of lateral shoots in apple and sweet cherry trees with only small reductions in shoot length (5, 6). This was considered to be particularly advantageous for nursery production of fruit trees because although apical dominance was temporarily interrupted prior to the induction of branching, there was no long-term reduction or deformation of terminal meristem growth (6). These characteristics would also be advantageous in the production of many woody landscape shrub species. This study was intended to evaluate the potential of CYC to promote branching of landscape shrubs in nursery production without long-term growth reduction.

Materials and Methods

Experiments were conducted in 2005 and 2006. The plants utilized were grown in a medium consisting of 92% aged pine bark and 8% coarse sand, amended with 5.4 kg/m^3 (9 lb/yd^3) Osmocote 18N–2.6P–10K (18–6–12, Scotts-Sierra Horticultural Products Co., Marysville, OH) and 0.9 kg/m^3 (1.5 lb/yd^3) Micromax (Scotts-Sierra Horticultural Products Co.). The plants were placed outdoors in full sun and irrigated overhead twice daily to provide a total of approximately 2.5 cm (1 in) of water. CYC treatments, which were supplemented with Latron B-1956 spreader/sticker at 0.06% (Rohm

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and Haas Co., Philadelphia, PA), were applied to wet the foliage using a CO_2-pressurized sprayer with a TXVS-8 cone-jet nozzle (R&D Sprayers, Opelousas, LA). Volume applied per plant varied depending on species due to differences in plant size but generally conformed to a rate of 0.2 liter/m^2 (2 qt/100 ft^2) of surface area. All experiments utilized randomized complete-block designs with four or five single-plant replications, blocked by plant size. Plant height, width, and quality data were subjected to analysis of variance using SAS General Linear Model procedure (SAS Institute, Cary, NC). New shoot count and measurement data from two selected stems per plant were analyzed as repeated measures utilizing SAS PROC MIXED with the REPEATED sub-command. Orthogonal contrasts were used to test cyclanilide concentration trend responses and comparisons between selected treatments at $P \leq 0.05$. Contrast coefficients for unequal treatment levels were calculated using the program of Khanizadeh and Fanous (10). Each species evaluated was analyzed as a separate experiment.

2005 Experiments. *Lagerstroemia indica ×fauriei* 'Muskogee' (crape myrtle) and *Photinia ×fraseri* (Fraser photinia) plants in 3.8 liter (#1) containers were repotted into 11.4 liter (#3) containers in early March 2005. Liners of *Ilex glabra* 'Compacta' (inkberry holly), *Rhaphiolepis indica* 'Pinkie' (Indian hawthorn), and *Pinus thunbergii* (Japanese black pine) were repotted into 3.8 liter (#1) containers also in early March 2005. Treatments were applied to the photinia, Indian hawthorn, and inkberry holly on May 21, and to Japanese black pine and crape myrtle on May 27. At time of treatment, crape myrtle plants averaged 80 cm (32 in) in height and 70 cm in width, photinia averaged 64 cm (25 in) high and 51 cm (20 in) wide, inkberry holly averaged 38 cm (15 in) high and 33 cm (13 in) wide, Indian hawthorn averaged 20 cm (8 in) high, 25 cm (10 in) wide, and black pine averaged 28 cm (11 in) high and 15 cm (6 in) wide. All plants appeared normal and healthy. Temperature and relative humidity were approximately 16C (61F) and 75%, respectively, for the May 21 applications, and 25C (77F), with 54% relative humidity for the May 27 applications. All plants were actively growing at the time of application except Indian hawthorn and Japanese black pine, both of which had completed an earlier growth flush. Treatments consisted of a single CYC spray application at 0, 54, 106, or 212 ppm (a.i.). An additional treatment of 106 ppm cyclanilide applied twice was also included. The second application of this treatment was on June 10 for all species, providing a two-week interval between applications for crape myrtle and black pine, and a three-week interval for photinia, Indian hawthorn, and holly. Temperature and relative humidity for the June 10 application were approximately 26C (79F) and 79%, respectively. One to two days before treatments were applied, two unbranched, actively growing and relatively uniform shoots were selected at or near the periphery of each plant, measured for length, and tagged for future measurement and new shoot counts. For Indian hawthorn and Japanese black pine, which had completed a growth flush, two sparsely-branched, relatively uniform shoots were selected at or near the periphery of each plant, tagged, and the existing lateral branches counted and measured for length to determine future shoot development. Treatments were arranged in a randomized complete block design within species, with five plants per treatment. On July 12 [7 weeks after treatment (WAT)], crape myrtle heights and widths were measured (widest width and perpendicular to it) and the numbers and lengths of new shoots developing on the tagged stems were determined. Through the growing season, the crape myrtles were checked daily and the date when flower buds began to open was recorded for each plant to determine the mean number of days after treatment that flowering began. On September 30, the number of inflorescences that developed on each crape myrtle plant was counted, and the plants were evaluated for quality. Quality for crape myrtle was rated on a scale of 1 to 4 (1 = poor form, little or no branching, considerable leaf yellowing; 2 = increased branching compared to a rating of 1, moderate leaf yellowing; 3 = acceptable branching and form, little discoloration; 4 = excellent form, dense branching, no discoloration.) All plants were evaluated by the same person without knowledge of the treatments applied. On October 3 (18 WAT) the new shoots on the tagged stems were counted a second time to account for shoots developed during a second growth flush.

On September 19–20 (18 WAT) inkberry holly heights and widths (widest width and perpendicular to it) were measured. Numbers and lengths of new shoots developed on the tagged stems were determined, and quality ratings were assessed on a scale of 1 to 4 (1 = poor form, sparse branching; 2 = acceptable form, fair branching; 3 = good form, good branching; 4 = excellent form, excellent branching).

Photinia height and width measurements, new shoot counts, and quality ratings (1 = poor form, considerable leaf yellowing, blotching or curling; 2 = acceptable form, moderate leaf yellowing, blotching or curling; 3 = good branching and form, little discoloration or curling; 4 = excellent form, branching and color) were obtained September 28–29 (19 WAT). During the course of the experiment, photinia became naturally infected with entomosporium leaf spot, a common problem with this plant (3). In evaluating the plants, it became apparent that the CYC treatments could be affecting the severity of the leaf spot infestation. Therefore, a separate leaf spot rating was obtained on October 6 (1 = no leaf spot; 2 = 1–25% leaves spotted; 3 = 26–50% leaves spotted; 4 = 51–75% leaves spotted; 5 = 76–100% leaves spotted, considerable defoliation).

The Japanese black pine and the Indian hawthorn had no additional growth flushes following treatment applications, therefore, no data were collected on these plants during the year of treatment. These plants were over-wintered in a polyethylene-covered house for evaluation the following spring. Shoot counts were obtained on these plants on May 5, 2006, following the first spring growth flush (1 year after treatment).

2006 Experiments. Plants in this study included *Rhododendron* 'Girard Rose' (hybrid azalea), *Rhaphiolepis indica* Eleanor Taber™ (Indian hawthorn), and *Photinia ×fraseri* (Fraser photinia). The azaleas and the Indian hawthorn were repotted from 3.8 liter (#1) containers into 11.4 liter (#3) containers in the fall of 2005. Photinia liners were potted into 11.4 liter (#3) containers in February, 2006. At time of treatment the azaleas averaged 33 cm (13 in) high and 41 cm (16 in) wide; the Indian hawthorn averaged 28 cm (11 in) high, 40 cm (16 in) wide; the photinia averaged 30 cm (12 in) high and 32 cm (12.5 in) wide. All plants had a normal, healthy appearance and were actively growing. Treatments for the azalea and the Indian hawthorn included CYC applied once at 0, 54, 106, or 212 ppm (a.i.) or, two applications (three-week interval) at 54 or 106 ppm (a.i.). CYC treatments for the photinia were applied once at 27, 54, or 106 ppm or, twice at 27 or 54 ppm. Additional photinia plants received the same treatments as above plus applications of Armada fungicide (trifloxystrobin + triadimefon, Bayer Environmental Science, Research Triangle Park, NC), 0.45 g/liter (6 oz/100 gal) at 30 day intervals. The photinia/fungicide experiment was treated as a factorial experiment, i.e., there were eight plants receiving each of the CYC treatments, with four of these eight plants also receiving treatments of Armada (four replications of all combinations of CYC treatments with and without Armada). Entomosporium leaf spot inoculum was provided by spacing previously-infected photinia plants among the treated plants. Experimental design was a randomized complete block with four single-plant replications per treatment for each species.

Treatments were applied to the azaleas and the Indian hawthorns on April 11, 2006. Temperature and relative humidity were 17 to 19C (63–66F) and 31 to 36%, respectively. Two days before treatment applications, two relatively uniform stems were randomly selected from the previous season's growth and tagged. The number of lateral shoots, 3 mm (0.1 in) or longer in length, present or developing at that time on each tagged stem was recorded. The second application to azaleas and Indian hawthorns receiving two applications was made on May 2. Temperature was 16C (60F) and relative humidity was 50%.

On April 12, applications of Armada fungicide were initiated on those photinia plants designated to receive the CYC plus Armada combinations (four replications each). This was repeated at 30-day intervals through the month of July. On April 17, two actively growing, unbranched stems selected on each of the photinia plants, were measured for length, and tagged. CYC treatments at the rates indicated above were applied to the photinia on April 19, including those plants previously treated with Armada. Temperature and relative humidity were 19C (67F) and 51%, respectively. Photinia treatments receiving two applications were treated a second time on May 16 (four-week interval) when temperature and relative humidity were18C (64F) and 48%, respectively.

Shoots were counted and lengths measured on the previously tagged stems of the azaleas and Indian hawthorns on August 10–11 (17 WAT). New shoot numbers were determined by subtracting the original shoot count from the final count. Plant heights, widths, and quality ratings were also obtained at this time (quality rating for azalea: 1 = poor branching and/or poor leaf color, 2 = normal branching and color, 3 = dense branching and good color; quality rating for Indian hawthorn: 1 = leaf yellowing, blotching and/or stunted growth and sparse branching, 2 = moderate yellowing or sparse branching, 3 = good leaf color, average branching, 4 = good color and form, dense branching). A second growth flush occurred on Indian hawthorns after the August evaluation; therefore, the hawthorns were evaluated again on September 13 (22 WAT).

Shoots on previously tagged stems of photinia were counted and lengths measured on August 11 (16 WAT). The Armada treatments failed to control the entomosporium leaf spot, providing no apparent difference between Armada treated and untreated plants. Therefore, the Armada/CYC treatment combination plants were not included in the evaluation; only those receiving CYC treatments without applications of Armada were evaluated (four replications per treatment). On August 15, heights, widths, and quality ratings were obtained (1 = dead or almost dead; 2 = severe defoliation, remaining leaves yellow or with yellow blotches and severe leaf spot; 3 = some defoliation, yellowing and leaf spot; 4 = normal healthy plant).

Results and Discussion

2005 Experiments. '**Muskogee' Crape myrtle.** There was a linear increase in the number of lateral shoots induced on tagged stems with increasing CYC concentration when counted at 7 WAT and at 18 WAT (Table 1). The largest num-

Table 1. Effects of cyclanilide on shoot development and flowering of 'Muskogee' crape myrtle, 2005.

Cyclanilide conc. (ppm)	Number of new shoots per stem[z] 7 WAT[y]	18 WAT	Days after treatment to flower	Quality rating[x]
0	0.4	3.5	54	3.0
54	5.2	9.7	67	3.8
106	5.1	10.5	73	3.4
212	10.7	12.0	91	3.0
Significance[w]	L***	L**	L**	Q*
106 × 2[v]	9.4	15.5	83	4.0
Contrasts[u]				
106 × 2 vs. 0	****	***	*	**
106 × 2 vs. 54	*	NS	NS	NS
106 × 2 vs. 106	*	NS	NS	NS
106 × 2 vs. 212	NS	NS	NS	**

[z]New shoots developed on previously unbranched stems tagged prior to treatment.

[y]WAT = weeks after treatment.

[x]Quality rating: 1 = poor form, little or no branching, considerable leaf yellowing; 2 = some branching, moderate leaf yellowing; 3 = acceptable branching and form, little discoloration; 4 = excellent form, dense branching, no discoloration.

[w]Non-significant (NS), linear (L), or quadratic (Q) response at the 5% (*), 1% (**), or 0.1% (***) level. Control included in trend analysis (n = 5).

[v]106 ppm cyclanilide applied twice at an interval of 2 weeks.

[u]Non-significant (NS) or significant at the 5% (*), 1% (**),0.1% (***), or 0.01% (****) level (n = 5).

Table 2. Effects of cyclanilide on shoot development and other factors of three nursery crop species, 2005.

Cyclanilide conc. (ppm)	'Compacta' holly		Fraser photinia		'Pinkie' Indian hawthorn	
	Shoot no. per stem[z]	Quality rating[y]	Shoot no. per stem	Leaf spot rating[x]	Shoot no. per plant	Inflorescence number
0	0.1	2.4	2.0	2.2	26	26
54	4.0	3.0	5.3	4.4	42	12
106	3.8	3.0	5.8	4.0	35	7
212	3.9	3.6	8.2	4.6	99	6
Significance[w]	Q**	L**	L****	C**	L**	L****
106 × 2[v]	6.2	3.4	8.3	4.2	112	7
Contrasts[u]						
106 × 2 vs. 0	****	*	****	***	***	**
106 × 2 vs. 54	**	NS	*	NS	**	NS
106 × 2 vs. 106	**	NS	NS	NS	**	NS
106 × 2 vs. 212	**	NS	NS	NS	NS	NS

[z]New shoots developed on stems counted and tagged prior to treatment.

[y]Quality rating: 1 = poor form, sparse branching; 2 = acceptable form, fair branching; 3 = good form and branching; 4 = excellent form and branching.

[x]Leaf spot rating: 1 = no leaf spot; 2 = 1–25% leaves spotted; 3 = 26–50% leaves spotted; 4 = 51–75% leaves spotted; 5 = 76–100% leaves spotted, considerable defoliation.

[w]Linear (L), quadratic (Q), or cubic (C) response at the 1% (**) or 0.01% (****) level. Control included in the trend analysis (n = 5).

[v]106 ppm cyclanilide applied twice at an interval of 2 weeks.

[u]Non-significant (NS) or significant at the 5% (*), 1% (**), 0.1% (***), or 0.01% (****) level (n = 5).

ber of lateral shoots per stem was 15.5 from CYC applied twice at 106 ppm vs. 3.5 for control plants when evaluated 18 WAT, although this was not greater than for 54 ppm, 106 ppm or 212 ppm applied once. The length of lateral shoots on CYC-treated plants appeared reduced compared to control plants when measurements were made 7 WAT but a statistical comparison with the controls could not be made because there were insufficient lateral shoots to measure on the control plants at that time (data not shown). CYC treatments did not significantly affect plant height or width (data not shown). However the increased lateral branching of CYC-treated plants resulted in a more compact, fuller appearance. There was a quadratic quality rating response with increasing CYC concentration, with the highest rating for a single application occurring at 54 ppm. All plants had acceptable quality ratings, although the 212 ppm treatment ratings were somewhat lower than other CYC treatments due to a slight yellowing of some of the leaves. This discoloration was not apparent on plants treated twice with 106 ppm CYC. CYC applications resulted in a delay in flowering, with a linear increase in days after treatment to flower with increasing CYC concentration (Table 1). This delay in flowering may be advantageous during nursery production, as it allows energy that would be used for flowering to be directed toward more vegetative growth and branching early in the season (12). There was no difference in total number of inflorescences produced during the season due to CYC treatment (data not shown).

'Compacta' inkberry holly. Approximately three weeks after treatment, a dark red discoloration was observed on new leaves of CYC-treated plants. However, as the leaves matured, the red color faded and normal green color developed. Treatments had no effect on plant heights or widths (data not shown) but a quadratic increase in lateral branch numbers was observed with increasing CYC concentration (Table 2). The greatest increase in lateral branching occurred with 106 ppm applied twice, with approximately six new lateral shoots per stem vs. four for the other CYC treatments and 0.1 for the controls. Treatments had no effect on new shoot length (data not shown). CYC treatments gave the plants a fuller, more densely-branched appearance that resulted in a linear increase in quality ratings with increasing CYC concentration (Table 2).

Fraser photinia. CYC treatments provided a linear increase in the number of lateral shoots induced, with the greatest number of new shoots (approx. eight per stem) developing with CYC applied at 212 ppm and at 106 ppm applied twice vs. two new shoots per stem for the control plants (Table 2). However, all CYC-treated plants had low quality ratings due to apparent phytotoxicity symptoms of leaf yellowing, blotching and curling (data not shown). In addition, the CYC-treated plants were more severely infected with entomosporium leaf spot than the control plants (Table 2). The CYC treatments appeared to increase the susceptibility of Fraser photinia to this disease. The period of susceptibility for Fraser photinia is when new shoots and leaves are still immature (3). Possibly the promotion of new shoot initiation prolongs the period of susceptibility and/or increases the amount of leaf surface susceptible to entomosporium infection. There were no differences in plant heights or widths resulting from CYC treatments (data not shown).

'Pinkie' Indian hawthorn. These plants failed to produce a flush of growth after they were treated in May of 2005, therefore, they were not evaluated during the 2005 growing season. However, after over-wintering in a polyethylene-covered house, a new growth flush occurred and shoot and inflorescence counts were obtained in May 2006 (1 year after treatment). There was a linear increase in new shoots, but a corresponding linear decrease in inflorescence numbers in response to increasing CYC concentration (Table 2). The greatest number of new shoots occurred with the 212 ppm treatment and the 106 ppm treatment applied twice (99 and

Table 3. **Effects of cyclanilide on shoot development of 'Girard Rose' azalea and Eleanor Taber™ Indian hawthorn, 2006.**

Cyclanilide conc. (ppm)	'Girard Rose' azalea: Shoot no. per stem[z]	'Girard Rose' azalea: Shoot length (cm)	'Girard Rose' azalea: Quality rating[y]	Eleanor Taber™ Indian hawthorn: Shoot number per stem
0	0.8	7.2	1.8	0.1
54	1.0	5.2	2.3	0.5
106	2.1	5.1	2.3	1.8
212	2.0	5.0	3.0	1.3
Significance[x]	L*	L**	L**	L*
54 × 2[w]	2.9	4.0	2.5	1.8
106 × 2	3.9	3.4	3.0	1.8
Contrasts[v]				
54 × 2 vs. 54	**	*	NS	**
54 × 2 vs. 106	NS	*	NS	NS
106 × 2 vs. 54	***	**	NS	**
106 × 2 vs. 106	**	**	NS	NS
106 × 2 vs. 212	**	**	NS	NS

[z]New shoots developed on stems counted and tagged prior to treatment.

[y]Quality rating: 1 = poor branching and/or poor color; 2 = normal branching and color; 3 = dense branching and good color.

[x]Linear (L) response at the 5% (*) or 1% (**) level. Control included in trend analysis (n = 4).

[w]Cyclanilide treatments applied twice at an interval of 3 weeks.

[v]Contrasts non-significant (NS) or significant at the 5% (*), 1% (**), or 0.1% (***) level (n = 4).

112 shoots, respectively, vs. 26 for the controls). However, these plants also had the lowest inflorescence numbers (6 and 7 respectively, vs. 26 for the controls). Although Indian hawthorn is also susceptible to entomosporium leaf spot, infection overall was very light, with no apparent increase on CYC-treated plants. Height, width and quality were not evaluated for these plants.

Japanese black pine. These plants also failed to produce a growth flush after treatment in 2005. After overwintering, there was a new growth flush in the spring of 2006 but there were no significant differences among treatments (data not shown). Japanese black pine apparently does not respond to CYC at the concentrations evaluated.

2006 Experiments. **'Girard Rose' azalea.** There was a linear increase in the number of new shoots induced (1 to 2 new shoots per stem, respectively, vs. 0.8 for the controls) along with a linear increase in plant quality rating as single applications of CYC increased from 54 to 212 ppm (Table 3). However, greater increases in shoot numbers were obtained with two applications at 54 and 106 ppm (2.9 and 3.9 new shoots, respectively). High quality ratings obtained with increased CYC concentration or application numbers reflect dense branching and good leaf color (no discoloration). No phytotoxicity symptoms were observed on the azaleas as a result of the CYC treatments. The length of the new shoots decreased linearly with increasing application rates but this did not significantly affect overall plant size (height and width, data not shown).

Eleanor Taber™ Indian hawthorn. Evaluation after the first growth flush did not show a significant increase in shoot numbers (data not shown), however, after the second growth flush (22 WAT) shoot counts of Indian hawthorn increased linearly in response to CYC concentration (Table 3). For the single applications, greatest shoot increases occurred with 106 ppm CYC (1.8 new shoots per stem vs. 0.1 for the controls). Equal shoot counts were obtained with 2 applications at 54 and 106 ppm. Plants treated with the 106 ppm concentration applied twice had some leaf reddening, yellowing and blotching when evaluated after the first growth flush. However, these symptoms were no longer apparent by the second evaluation and quality ratings were not significantly different among treatments, probably because most plants, regardless of treatment, were considered to be of a marketable quality (data not shown). There were no differences in new shoot lengths or plant size among treatments at either evaluation period (data not shown).

Fraser Photinia. Although there was a linear increase in new shoots induced by single applications of CYC with increasing concentrations, there was a corresponding quadratic decrease in quality ratings due to combined effects of increased entomosporium leaf spot severity on CYC-treated plants, and phytotoxicity symptoms of leaf yellowing and blotching (Table 4). These symptoms, which included defoliation, were all included in a single quality rating because it was frequently not possible to distinguish leaf spot symptoms from phytotoxicity, particularly when defoliation was involved. Plants widths were also negatively affected by CYC applications. This could be the result of overall poor health of these plants. Entomosporium disease was more severe than in the 2005 experiment, probably because disease pressure was intentionally increased by including already diseased plants in close proximity to the experimental area. The Armada (fungicide) treatments failed to control entomosporium disease at the rate and frequency applied. Therefore, the Armada-treated plants were not included in the evaluation.

In these experiments, single foliar applications of CYC at 0, 54, 106 or 212 ppm stimulated a linear increase in lateral shoot development for 'Muscogee' crape myrtle, 'Pinkie' and Eleanor Taber™ Indian hawthorn, 'Girard Rose' azalea, and Fraser photinia, and a quadratic increase for 'Compacta' inkberry holly. In most cases, increased shoot development re-

Table 4. **Effects of cyclanilide on growth, shoot development, and quality of Fraser photinia, 2006.**

Cyclanilide conc. (ppm)	Shoot number per stem[z]	Quality rating[y]	Plant width[x] (cm)
0	0.3	2.5	52
27	1.6	2.3	45
54	2.4	1.5	39
106	3.1	2.0	42
Significance[w]	L**	Q*	L*
27 × 2[v]	1.4	1.3	34
54 × 2	0.9	1.8	42
Contrasts[u]			
27 × 2 vs. 27	NS	**	**
27 × 2 vs. 54	NS	NS	NS
54 × 2 vs. 27	NS	NS	NS
54 × 2 vs. 54	NS	NS	NS
54 × 2 vs. 106	NS	NS	NS

[z]New shoots developed on unbranched stems tagged prior to treatment.

[y]Quality rating: 1 = dead or almost dead; 2 = severe defoliation, remaining leaves yellow or with yellow blotches and severe leaf spot; 3 = some defoliation, yellowing and leaf spot; 4 = normal healthy plant.

[x]Width = (widest width + width perpendicular) ÷ 2.

[w]Linear (L) or quadratic (Q) response at the 5% (*) or 1% (**) level. Control included in trend analysis (n = 4).

[v]Cyclanilide treatments applied twice at an interval of 4 weeks.

[u]Contrasts non-significant (NS) or significant at the 1% (**) level (n = 4).

sulted in plants with a fuller appearance and improved plant quality. However, CYC applications to Fraser photinia caused phytotoxicity symptoms of leaf yellowing, blotching, and curling, and increased susceptibility to entomosporium leaf spot, resulting in low plant quality for CYC treated plants. CYC failed to promote branching of Japanese black pine at the concentrations tested.

Repeat applications of CYC at either 54 or 106 ppm promoted increased shoot development over a single application for inkberry holly, 'Pinkie' Indian hawthorn, and 'Girard Rose' azalea. This is similar to the results of Oates et al. (14) who showed that multiple applications of benzyladenine were more effective in promoting branching of two cultivars of Indian hawthorn.

The importance of application timing may be illustrated by the branching responses of the two cultivars of Indian hawthorn in this study. A late application to 'Pinkie' in May, 2005 after the spring growth flush was mature failed to promote branching over the remainder of that growing season. When a new growth flush occurred the following spring, there was a significant linear increase in branching on the CYC-treated plants, but also a linear decrease in inflorescence numbers. CYC applications to Eleanor Taber™ in April, 2006, when shoots were actively growing resulted in a growth flush in late summer of the same season.

Effects of CYC on plant heights and widths were generally minimal for most species evaluated. This is consistent with the results of Elfving and Visser (5, 6) who found only small reductions in shoot growth with applications to apple and sweet cherry trees. With Fraser photinia there was a reduction in width in 2006, however, this was probably due to poor plant health and extensive defoliation resulting from severe leaf spot on treated plants. In addition to the phytotoxicity symptoms previously noted on Fraser photinia, some foliar discoloration occurred on three additional species: minor to moderate yellowing occurred on 'Muskogee' crape myrtle and Eleanor Taber™ Indian hawthorn, and a reddening of the new foliage of 'Compacta' inkberry holly was observed, which was actually rather attractive. This red coloration dissipated as the holly leaves matured. The yellowing of the Indian hawthorn and crape myrtle leaves dissipated by the end of the growing season.

In general, the results of this study suggest that, with the exceptions of Fraser photinia and Japanese black pine, CYC has considerable potential for use as a branching agent in nursery production of several woody landscape species.

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