Drench Application of Cyclanilide Promotes Shoot Development in Containerized Woody Landscape Species during Nursery Production[1]

Z. Williamson[2], G.J. Keever[3], J.R. Kessler[3], and J.W. Olive[4]
Department of Horticulture
Auburn University, AL 36849

Abstract

Cyclanilide (CYC), a plant growth regulator with cytokinin-like properties, was applied as a substrate drench to containerized woody ornamentals to determine its effects on plant growth. At 70 days after treatment (DAT) in 2005, drench applications of 50 to 1,000 ppm CYC had increased shoot development 7 to 74% for 'Alabama Beauty' sasanqua camellia (*Camellia sasanqua* 'Alabama Beauty'), 63 to 205% for small anisetree (*Illicium parviflorum*), 21 to 74% for 'Snow White' Indian hawthorn (*Rhaphiolepis indica* 'Snow White'), and 266 to 626% for 'Sky Pencil' holly (*Ilex crenata* 'Sky Pencil'), when compared to control plants. Shoot counts the following spring, 270 DAT, increased from 16 to 101% for sasanqua camellia, 42 to 158% for small anisetree, 121 to 241% for Indian hawthorn, and 33 to 167% for 'Firepower' nandina, when compared to control plants. At 30 DAT foliar injury to sasanqua camellia, Indian hawthorn, and small anisetree increased with CYC concentration, and application of 500 or 1,000 ppm CYC resulted in severe injury or death of small anisetree and 'Snow White' Indian hawthorn. At 75 DAT in 2006, drench application of 25 to 100 ppm CYC had increased shoot counts of Eleanor Taber™ Indian hawthorn from 100 to 218%, when compared to controls, and quality ratings were highest at 130 DAT in plants drenched with 50 ppm CYC, although foliar injury ratings increased with CYC concentration at 75 and 130 DAT. At 60 DAT in 2007, application of 10 to 40 ppm CYC had increased shoot counts for 'Snow White' Indian hawthorn and 'Sky Pencil' holly 100 to 182% and 22 to 78%, respectively, and 96 to 171% and 30 to 63%, respectively at 90 to 110 DAT. In both species, quality ratings at 160 DAT increased with increasing CYC concentration. Single CYC drench applications were more persistent than previously reported single spray applications, effective at lower concentrations, and promoted shoot production in a species not responsive to single or multiple spray applications (*Nandina domestica*).

Index words: plant growth regulator, auxin transport inhibitor, lateral shoots, nursery production.

Species used in this study: Eleanor Taber™, Olivia™, and 'Snow White' Indian hawthorn [*Rhaphiolepis indica* (L.) Lindl.]; 'Sky Pencil' holly (*Ilex crenata* Thunb. 'Sky Pencil'); 'Little Gem' magnolia (*Magnolia grandiflora* L.'Little Gem'); 'Alabama Beauty' sasanqua camellia (*Camellia sasanqua* L. 'Alabama Beauty'); small anisetree (*Illicium parviflorum* Michx. ex Vent.); 'Firepower' nandina (*Nandina domestica* Thunb. 'Firepower'); 'Prostrata' spreading Japanese yew (*Cephalotaxus harringtonia* C. Koch. 'Prostrata').

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

Significance to the Nursery Industry

Previously, single foliar spray applications of 25 to 200 ppm cyclanilide (CYC) promoted increased shoot development by several woody landscape species during nursery production; however, the response was often limited to the growth flush after application (6, 8). Multiple spray applications of 100 to 300 ppm CYC promoted more new shoot development than single applications; however, transitory injury decreased marketability of sensitive species (7). In this study, CYC substrate drenches were shown to be a viable alternative to foliar sprays when applied at appropriate concentrations, which varied with species. Concentrations of drench-applied CYC that promoted increased shoot production with only transitory or no injury were 40 ppm for 'Sky Pencil' holly (*Ilex crenata* 'Sky Pencil') and Indian hawthorn (*Rhaphiolepis indica*), 50 ppm for small anisetree (*Illicium parviflorum*), 250 ppm for 'Alabama Beauty' sasanqua camellia (*Camellia sasanqua* 'Alabama Beauty'), and 500 ppm for 'Firepower' nandina (*Nandina domestica* 'Firepower'). Single CYC drench applications were more persistent than single spray applications, effective at lower concentrations, and promoted shoot production in a species unresponsive to single or multiple spray applications (*Nandina domestica*). As with foliar sprays, tolerances to CYC varied widely among species in response to substrate drenches indicating irreversible injury is a risk from application of supraoptimal concentrations.

Introduction

Apical dominance, the suppression of lateral bud outgrowth by auxins produced in shoot apices, is broken when terminal shoots are removed (3, 9). This process has practical implications during the production of most woody ornamental shrubs that usually require pruning multiple times to promote the dense canopy preferred by consumers (1, 9, 13). However, pruning is labor intensive and the tissue removed during pruning increases production time by at least 3 weeks per pruning (13). Exogenous application of cytokinins or plant growth regulators (PGRs) with cytokinin-like activity also can reduce apical dominance by counteracting auxins (3). 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 the outgrowth of latent lateral buds (11). In research conducted on apple and sweet cherry, single foliar applications of 25 to 200 ppm CYC promoted lateral shoot development on current and previous season's wood, but long-term leaf or meristem morphology were unaffected (4, 5).

The prospect of promoting lateral shoot development without affecting long term morphology made CYC an ideal candidate for application to ornamental species. During

[1]Received for publication April 3, 2009; in revised form June 26, 2009.
[2]Graduate Assistant.
[3]Professors. keevegj@auburn.edu
[4]Ornamental Horticulture Research Center, Mobile, AL 36608.

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-07-18 via free access

initial testing, single foliar applications of 25 to 200 ppm CYC increased lateral shoot counts on 12 of 19 ornamental species tested (6). Foliar injury, if it occurred, was transitory and quality of treated plants was generally higher than controls; however, increased lateral shoot production was often limited to the growth flush after treatment, and plants often appeared similar to controls 6 to 7 months after treatment (6). In a later study, up to 5 weekly or biweekly applications of 100 to 300 ppm CYC were applied to species responsive or unresponsive to single spray applications (7). Three applications increased shoot counts and usually improved quality of 'Sky Pencil' and 'Fosteri' hollies, Olivia™ and Eleanor Taber™ Indian hawthorns, and 'Brandy's Temper' camellia when compared to controls. Species that failed to respond to single applications also failed to respond to five applications of CYC.

Many plant growth regulators (PGRs) are active when applied as foliar sprays or root zone drenches (2, 11, 12). When compared to spray applications, drench applications usually elicit a more persistent and uniform response, are active at lower concentrations, and can induce a response by species that fail to respond to spray applications (2, 11, 12). A drench application is more labor intensive to apply than a single foliar spray; however, in previous studies multiple foliar applications were more persistent than single foliar applications, increasing the labor required (2, 11, 12). In previous work, CYC was effective as a drench when applied to in-ground cherry trees, but required up to ten times higher concentration than a foliar spray, possibly because only a small portion of the root zone was treated (Bayer Environmental Sciences, pers. comm.). Because containers restrict root systems, applying drenches to the entire root system with a relatively small volume is possible. The objective of this study was to determine the efficacy of a single CYC drench application in promoting shoot production while avoiding or minimizing foliar injury that could impact marketability of woody ornamental nursery crops.

Materials and Methods

Experiments were conducted in 2005 at the Ornamental Horticulture Research Center in Mobile, AL, and in 2006 and 2007 on Auburn University's main campus in Auburn, AL, using similar methodology unless otherwise noted.

Experiment 1. Uniform plants of 'Alabama Beauty' sasanqua camellia (*Camellia sasanqua* 'Alabama Beauty'), small anisetree (*Illicium parviflorum*), 'Snow White' Indian hawthorn (*Rhaphiolepis indica* 'Snow White'), 'Sky Pencil' holly (*Ilex crenata* 'Sky Pencil'), 'Firepower' nandina (*Nandina domestica* 'Firepower'), and 'Little Gem' magnolia (*Magnolia grandiflora* 'Little Gem') in 3.8 liter (#1) containers of an amended pine bark:sand mix (7:1 by vol) obtained from Tom Dodd Nurseries in Semmes, AL, were spaced on an unshaded nursery pad or under 47% shade cloth (small anisetree) and irrigated with overhead impact sprinklers applied twice daily, totaling about 2.5 cm (1.0 in). 'Little Gem' magnolia was repotted prior to treatment into 7.6 liter (#2) containers of a 3:1 pinebark:peatmoss medium amended per m^3 (yd^3) with 1.2 kg (2.0 lb) gypsum, 8.3 kg (14.0 lb) 16.5N-3.0P-10K slow-release fertilizer (Osmocote 17-7-12, The Scotts Company, Marysville, OH), 0.9 kg (1.5 lb) Micromax (The Scotts Company), and 3.6 kg (6.0 lb) dolomitic limestone. Substrate pH was between 5.5 and 6.0. With no prior knowledge of appropriate drench concentrations on containerized species, a wide range of concentrations was initially tested. On July 13, 2005, single 250-ml substrate drenches of 0, 50, 100, 250, 500, or 1,000 ppm CYC (Bayer Environmental Science, Research Triangle Park, NC) were applied to moist container medium. Application of 250 ml per pot resulted in leachate volumes of 50 to 75 ml (1.7 to 2.5 fl oz) from 3.8 liter (#1) containers and < 10% from 7.6 liter (#2) containers. After a minimum of 6 hours, plants were returned to the nursery pad. Treatments were completely randomized within species and replicated with five single plants.

Data collection included a rating of plant injury, if applicable, at 30 days after treatment (DAT). The injury rating scale was: 1 = no injury; 2 = slight yellowing of new growth, slight cupping of new foliage; 3 = moderate yellowing of new growth, moderate cupping, twisting and/or stunting of new foliage; 4 = severe yellowing and necrosis of new foliage, severe stunting, twisting, and/or cupping of new foliage; and 5 = plant death. At 70 DAT, plant height and widths [mean width = (widest width + width 90° to widest width) ÷ 2] were recorded and new lateral and terminal shoots ≥ 1 cm (0.4 in) in length were counted. New shoots on sasanqua camellia, small anisetree, Indian hawthorn, and nandina were counted again on April 12, 2006, 270 DAT. Data analyses included an analysis of variance using PROC GLM (SAS version 9.1.3, SAS Institute, Cary, NC) for all response data except injury rating. Orthogonal polynomial contrasts were used for trend analysis at $\alpha = 0.05$, PROC GENMOD was used to analyze injury rating with the multinomial probability distribution, and median treatment values were reported.

Experiment 2. Eleanor Taber™ Indian hawthorn and 'Prostrata' spreading yew (*Cephalotaxus harringtonia* 'Prostrata') liners were repotted on March 27, 2006, into 3.8 liter (#1) containers using a 7:1 pinebark:sand medium (pH 5.5–6.0) amended per m^3 (yd^3) with 9.5 kg (16 lb) 17N-2.6P-10K (PolyOn 17-6-12, Pursell Industries, Sylacauga, AL), 0.9 kg (1.5 lb) Micromax and 3 kg (5 lb) dolomitic limestone. On July 12, CYC substrate drenches of 0, 25, 50, 75, or 100 ppm were applied to moist container medium. Plants received 200 ml (6.8 fl oz) per pot, resulting in leachate volumes of about 10%. Treatments were completely randomized and replicated with ten single plants.

New terminal and lateral shoots ≥ 1 cm (0.4 in) in length were counted at 75 DAT, and plant height, average width, and injury rating (1 = no injury; 2 = slight discoloration of new leaves; 3 = slight discoloration and cupping of new leaves; 4 = moderate discoloration and cupping of new leaves; 5 = severe discoloration and twisting of new leaves) were determined at 75 and 130 DAT. Plant quality was assessed on a scale of 1 to 5 (1 = minimal branching, open and leggy to 5 = prolific branching, dense and compact) at 130 DAT. Data analyses were the same as in experiment 1. PROC GENMOD was used to analyze quality rating with the multinomial probability distribution.

Experiment 3. Uniform liners of 'Snow White' Indian hawthorn in 32-cell flats and 'Sky Pencil' holly in 50-cell flats were repotted into 0.95 liter (qt) pots on November 27, 2006, and January 23, 2007, respectively, using the previously described substrate (experiment 2). Plants were overwintered outdoors in full sun, and covered with perforated white polyethylene sheets when freezing temperatures were

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-07-18 via free access

forecast. On May 30, 2007, after the spring growth flush had matured, 'Sky Pencil' holly and 'Snow White' Indian hawthorn received single substrate drenches of 0, 10, 20, 30, or 40 ppm CYC in 150 ml (5.1 fl oz) per pot. Substrate was moist, and plants were irrigated the following day to allow maximum absorption. Treatments were completely randomized within species and replicated with eight ('Sky Pencil' holly) or ten ('Snow White' Indian hawthorn) single plants. On July 1 plants were repotted into 3.8 liter (#1) containers using the same substrate. Data analyses were the same as in experiment 2.

Data collection included new shoot counts at 60 and 90 to 110 DAT, plant height and widths at 60 and 160 DAT, and a quality rating at 160 DAT. Shoot counts were taken over a period of time (90 to 110 DAT) due to differences among treatments in timing of new shoot development.

Results and Discussion

Experiment 1. At 70 DAT, shoot counts in 'Alabama Beauty' sasanqua camellia changed quadratically in response to increasing CYC concentration, with plants drenched with 50, 100, 250, 500, or 1,000 ppm CYC forming 7, 36, 71, 64 or 21%, respectively, more shoots than control plants (Table 1). At 270 DAT, shoot counts of sasanqua camellia increased linearly as CYC concentration increased, and plants drenched with 50, 100, 250, 500, or 1,000 ppm CYC had formed 50, 15, 70, 90 or 100%, respectively, more shoots than control plants. This stimulation in shoot development in the spring following drench application of CYC the previous year indicated a persistent effect that was absent with single or multiple spray applications of CYC to camellia (6, 7). At 70 DAT plant height decreased linearly and width increased linearly with increasing CYC concentration (Table 1). Similarly, in a previous study height of 'Brandy's Temper' sasanqua camellia decreased linearly without affecting growth index as foliar spray concentrations of CYC increased, indicating the formation of a wider canopy (6). Median injury ratings at 30 DAT were higher for plants treated with 500 or 1000 ppm CYC, but similar for plants receiving lower CYC concentrations and control plants (data not shown). The only injury symptom on 'Alabama Beauty' sasanqua camellia was immature foliage that appeared lighter green than that of control plants. In a previous study (7), 3 weekly foliar applications of 100 to 300 ppm CYC resulted in transitory injury, limited to attractive reddening of new growth, in 'Brandy's Temper' sasanqua camellia that persisted until 90 DAT (7), whereas in an unpublished study three foliar applications of 200 ppm CYC at a 1, 2, or 3 week interval did not injure 'Diana' sasanqua camellia. In all of these studies, symptoms were minor, suggesting a relatively high tolerance of sasanqua camellia to drench or foliar-applied CYC. These results indicated that drench application of 250 ppm CYC to sasanqua camellias can increase lateral shoot production without the loss of plant biomass associated with pruning (13).

At 70 and 270 DAT, shoot counts for small anisetree changed quadratically in response to increasing CYC concentration (Table 1). At 70 DAT, small anisetree treated with 50, 100, 250, 500, or 1,000 ppm CYC formed 63, 63, 188, 213, or 88%, respectively, more new shoots than control plants. At 270 DAT, shoot counts in small anisetree drenched with 50, 100, 250, 500, or 1000 ppm CYC formed 56, 94, 156, 75 or 44%, respectively, more new shoots than control plants. However, small anisetree was extremely sensitive to

Table 1. Effects of various concentrations of cyclanilide drench applications on growth of four woody ornamentals, expt. 1.

Concentration (ppm)	Injury rating[z]	Shoot counts[y]		Plant height (cm)	Plant width[x] (cm)
	30 DAT	70 DAT	270 DAT	70 DAT	70 DAT
'Alabama Beauty' sasanqua camellia					
0	1	14	20	74.2	26.4
50	1	15	30	76.8	31.1
100	1	19	23	76.8	33.3
250	1	24	34	69.2	37.6
500	2	23	38	67.6	35.9
1000	2	17	40	52.8	37.0
Sign.[w]	L***	Q***	L***	L***	L*
Small anisetree					
0	1	8	16	74.2	29.6
50	2	13	25	76.8	28.3
100	2	13	31	76.8	21.9
250	3	23	41	69.2	23.1
500	5	25	28	67.6	24.5
1000	4	15	23	52.8	24.2
Sign.	L***	Q***	Q***	L***	NS
'Snow White' Indian hawthorn					
0	1	7	22	18.2	25.3
50	1	12	53	19.4	28.1
100	1	10	50	16.4	27.6
250	1	11	61	17.2	25.0
500	3	6	76	17.8	24.3
1000	3	9	59	15.5	28.0
Sign.	L***	C**	Q***	NS	NS
'Firepower' nandina					
0	—	3	3	28.0	34.3
50	—	4	4	28.8	33.3
100	—	3	3	33.0	34.6
250	—	3	4	29.0	30.5
500	—	3	8	27.8	30.2
1000	—	3	7	25.6	26.3
Sign.	—	NS	L***	NS	L*

[z]Median injury rating of new foliage: 1 = no injury; 2 = slight yellowing of new growth, slight cupping of new foliage; 3 = moderate yellowing of new growth, moderate cupping, twisting and/or stunting of new foliage; 4 = severe yellowing and necrosis of new foliage, severe stunting, twisting, and/or cupping of new foliage; and 5 = plant death.

[y]Total number of actively growing terminal and lateral shoots at 60 days after treatment (DAT) in 2005 and at 270 DAT in 2006.

[x]Average width = (widest width + width 90° to widest width) ÷ 2.

[w]CYC trend analysis of concentration nonsignificant (NS), linear (L), quadratic (Q), or cubic (C) at $\alpha = 0.05$ (*), 0.01 (**), or 0.001 (***).

drench-applied CYC. At 30 DAT, injury rating increased linearly with increasing concentration and included foliar chlorosis and necrosis and leaf curling that persisted until the experiment ended at 270 DAT. At 270 DAT 20% of the plants drenched with 250 CYC and 60% of those drenched with 500 or 1000 ppm CYC were dead and the remaining plants in these treatments were extremely chlorotic. At 70 DAT, height of small anisetree decreased linearly with increasing CYC concentration, whereas width was unaffected. In a

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-07-18 via free access

previous study, evaluating the efficacy of single foliar sprays of CYC, shoot counts in Florida anise (*Illicium floridanum*) changed quadratically with increasing CYC concentration (6). Florida anise sprayed with 50 ppm CYC formed the most new shoots, but applying higher concentrations failed to provide additional benefit. However, plants treated with a single spray of 50 to 200 ppm CYC lacked injury, indicating that the risk of irreversible injury or death is greater when CYC is applied as a drench to *Illicium*.

At 70 DAT, shoot counts for 'Snow White' Indian hawthorn changed cubically with increasing CYC concentration; plants drenched with 50, 100, 250, or 1,000 ppm CYC, but not 500 ppm CYC, formed 71, 43, 57, or 29%, respectively, more new shoots than controls (Table 1). At 270 DAT, new shoot counts for 'Snow White' Indian hawthorn changed quadratically with increasing concentration; plants drenched with 50, 100, 250, 500, or 1,000 ppm CYC formed 141, 127, 177, 246 or 168%, respectively, more new shoots than controls. As with small anisetree at 30 DAT, injury increased linearly with increasing CYC concentration and consisted of lighter green immature foliage, especially for plants drenched with 500 or 1000 ppm CYC. By 60 DAT, chlorosis was evident on plants drenched with 250 ppm CYC, and plants drenched with higher CYC concentrations were severely chlorotic or necrotic. Plants treated the previous summer with 500 ppm CYC flushed in February 2006 following a mild December and January with shorter internodes and small, burgundy leaves, symptoms of overdosage. Twenty and 80% of plants drenched the previous summer with 500 and 1000 ppm CYC, respectively, died. Based on this initial experiment, optimal concentrations for drench-applied CYC to promote branching, while avoiding or minimizing injury to Indian hawthorn, are 100 ppm or less.

At 70 DAT, shoot counts in 'Sky Pencil' holly increased linearly ($P \leq 0.001$) with increasing concentration, from an absence of new shoots on controls to 1, 13, 13, 13, or 25 new shoots in plants drenched with 50, 100, 250, 500, or 1,000 ppm CYC, respectively. CYC did not affect height or width of 'Sky Pencil' at 70 DAT, and CYC-treated plants lacked injury, except for slightly lighter green immature foliage. A similar appearance among all drenched plants coupled with the most new shoots on plants drenched with the highest CYC concentration (1,000 ppm) indicated that 'Sky Pencil' holly was very tolerant to CYC drench application. A similarly high tolerance to foliar sprays of CYC by 'Sky Pencil' holly has been reported (6, 7, 8).

New shoot counts for 'Firepower' nandina were unaffected by CYC treatments at 70 DAT in 2005; however, at 270 DAT in 2006 shoot counts in nandina increased linearly with CYC concentration (Table 1). 'Firepower' nandina drenched with 50, 250, 500, or 1,000 ppm CYC, but not with 100 ppm, had formed 33, 33, 167 or 133%, respectively, more new shoots when compared to controls. Plant width at 70 DAT decreased linearly with increasing concentration, and plants treated with 1000 ppm CYC appeared stunted. The CYC treatments failed to affect plant height. In previous studies, 'Harbour Dwarf' nandina failed to respond to a single CYC spray application (6) or 5 weekly spray applications (7), indicating that substrate drenches may provide an effective alternative when species are unresponsive to foliar sprays. However, cultivars may also differ in response to CYC, as reported with drench or spray applications of thidiazuron (10).

Southern magnolia showed no visible effects from drench-applied CYC (data not shown). Similarly, foliar applications failed to promote shoot production by *Magnolia* spp. (Bayer Environmental Science, unpublished data).

Five of the six species tested in experiment 1 increased shoot production in response to drench application of 50 to 1000 ppm CYC, either in the year of application or the following spring. These results indicated that substrate drenches were a potentially effective means of delivering CYC, often resulting in a longer branching response than previously reported with single or multiple foliar applications (6, 7). However, CYC concentrations of 250 ppm or higher often caused transitory or irreversible injury and occasionally plant death, indicating that optimal concentrations were lower than those applied in this experiment.

Experiment 2. At 75 DAT, shoot counts of Eleanor Taber™ Indian hawthorn changed quadratically in response to increasing CYC concentration. Plants drenched with 25, 50, 75, or 100 ppm CYC had formed 136, 218, 100, or 109%, respectively, more shoots than controls (Table 2). These percentages were much higher than those for Indian hawthorn at 70 DAT with 50 to 1000 ppm CYC in the first experiment. Plant height and width decreased linearly with increasing CYC concentration at 75 and 130 DAT. Injury ratings at 75 DAT and 130 DAT increased linearly with increasing CYC

Table 2. Effect of various concentrations of cyclanilide drench applications on growth of Eleanor Taber™ Indian hawthorn, expt. 2.

CYC conc. (ppm)	Shoot counts[z]	Plant height (cm)		Plant width[y] (cm)		Injury rating[x]		Quality rating[w]
	75 DAT	75 DAT	130 DAT	75 DAT	130 DAT	75 DAT	130 DAT	130 DAT
0	11	24.9	22.6	30.7	33.2	1	1	3
25	26	18.6	22.2	28.6	34.8	2	2	4
50	35	17.3	18.9	26.2	28.5	3	2	4
75	22	16.3	17.8	22.3	27.0	3	2	3
100	23	16.0	15.7	22.5	22.1	4	3	2
Sign.[v]	Q***	L***	L***	L***	L***	L***	L***	Q***

[z]Total number of actively growing terminal and lateral shoots quantified 75 days after treatment (DAT).

[y]Average width = (widest width + width 90° to widest width) ÷ 2.

[x]Median injury rating of new foliage: 1 = no injury; 2 = slight discoloration of new leaves; 3 = slight discoloration and cupping of new leaves; 4 = moderate discoloration and cupping of new leaves; 5 = severe discoloration and twisting of new leaves.

[w]Median quality rating: 1 = minimal branching, open and leggy to 5 = prolific branching, dense and compact.

[v]CYC trend analysis of concentration non-significant (NS), linear (L) or quadratic (Q) at $\alpha = 0.001$ (***).

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-07-18 via free access

concentration. Symptoms were restricted to immature foliage and consisted of bronzing, reduced leaf size, and cupping. At 130 DAT, quality ratings changed quadratically in response to increasing CYC concentration. Ratings of plants treated with 25 or 50 ppm CYC were higher than those of controls, whereas ratings of plants drenched with 100 ppm CYC were lower.

Drench application of CYC failed to affect shoot production in spreading Japanese yew (data not shown). These results concur with the findings of Holland et al. (6) in which a single foliar spray application of 25 to 200 ppm CYC failed to promote shoot development of spreading yew.

Optimal concentrations of drench-applied CYC are those that promote shoot development while minimizing or avoiding injury and result in higher quality plants. In this experiment, a substrate drench of 25 and 50 ppm CYC increased shoot development in Eleanor Taber™ Indian hawthorn 136 and 218%, respectively, resulted in higher quality plants, while causing minimal injury to immature foliage.

Experiment 3. In 2007, 'Snow White' Indian hawthorn drenched with 10, 20, 30, or 40 ppm CYC had formed 100, 112, 118, or 182%, respectively, more new shoots than controls at 60 DAT and 96, 125, 171, or 171% more new shoots at 90 to 110 DAT (Table 3). These increases were similar to those from the second experiment when 25 to 100 ppm CYC was applied to Eleanor Taber™ Indian hawthorn. Similar to experiment 2, plant height at 60 and 160 DAT decreased linearly with increasing CYC concentration. At 160 DAT, plant width had changed quadratically with increasing concentration, increasing with the application of 10 to 30 ppm CYC before decreasing slightly with the application of 40 ppm CYC. Injury that included reddening and slight cupping of new foliage, although not quantified, appeared to increase with increasing CYC concentration at 30 DAT. Injury was no longer evident at 160 DAT, except in plants drenched with 40 ppm CYC whose foliage maintained a reddish hue. While this symptom is abnormal, it did not adversely affect plant appearance. At 160 DAT, plant quality rating increased linearly with increasing CYC concentration, and CYC-treated plants were visibly more compact and branched than controls. 'Snow White' Indian hawthorn responded positively to 10 to 40 ppm CYC when applied as a substrate drench, with only a reddening and cupping of immature foliage that increased with concentration and was transitory, except when applied at 40 ppm. Even when applied at 40 ppm, adverse effects on foliage were absent at 160 DAT and resulted in plants with the highest quality ratings.

'Sky Pencil' holly drenched with 10, 20, 30, or 40 ppm CYC had formed 22, 30, 70, or 78%, respectively, more new shoots than controls at 60 DAT and 29, 41, 63, or 54% more new shoots at 90 to 110 DAT (Table 3). Height decreased linearly at 60 DAT but was unaffected at 160 DAT, indicating a dissipation of any height suppression. Plant width changed cubically at 160 DAT, with CYC-treated plants generally wider than controls. These treatment effects were relatively minor and may not be of commercial importance. Similar increases in plant width of 'Sky Pencil' holly were reported in response to foliar applications of CYC (7). This increase in width is considered desirable by nurserymen in a cultivar with a naturally narrow, upright growth habit. The only visible abnormal effect was a slight elongation of developing leaves; however, this change failed to affect plant quality. Quality rating at 160 DAT increased linearly with increasing CYC concentration, and treated plants were generally fuller and more compact than controls. These results were similar to the findings of Holland et al. (6, 7) in which foliar application of CYC to 'Sky Pencil' holly resulted in the formation of a more dense and compact plant canopy. The linear increases in shoot counts in response to 50 to 1000

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-07-18 via free access

Table 3. Effects of various concentrations of cyclanilide drench applications on growth of 'Snow White' Indian hawthorn and 'Sky Pencil' holly, expt. 3.

CYC conc. (ppm)	Shoot counts[z]		Plant height (cm)		Plant width[y] (cm)		Quality rating[x]
	60 DAT	90–110 DAT	60 DAT	160 DAT	60 DAT	160 DAT	160 DAT
'Snow White' Indian hawthorn							
0	17	24	20.6	27.0	26.1	39.5	2
10	34	47	19.4	25.0	28.5	43.9	3
20	36	54	19.0	24.7	25.3	42.1	3
30	37	65	18.9	23.8	25.6	43.0	4
40	48	65	18.2	23.8	24.9	41.5	5
Sign.[w]	L***	L***	L***	L**	NS	Q**	L***
'Sky Pencil' holly							
0	23	24	48.8	57.4	10.1	11.8	2
10	28	31	47.7	56.8	10.3	14.9	3
20	30	34	45.4	57.8	9.5	12.4	3
30	39	39	42.5	53.6	10.0	13.5	4
40	41	37	41.3	53.4	9.3	14.2	5
Sign.	L***	L***	L***	NS	NS	C**	L***

[z]Total number of actively growing terminal and lateral shoots quantified 60 and 120 days after treatment (DAT).
[y]Average width [(widest width + width 90° to widest width) ÷ 2].
[x]Median quality rating: 1 = minimal branching, open and leggy to 5 = prolific branching, dense and compact.
[w]CYC trend analysis of concentration non-significant (NS), linear (L), quadratic (Q), or cubic (C) at $\alpha = 0.01$ (**) or 0.001 (***).

ppm CYC in the first experiment and to 10 to 40 ppm CYC in this experiment and only mild abnormal foliar symptoms (lighter green foliage and more elongated leaves) indicated that 'Sky Pencil' holly was responsive to a wide range of CYC concentrations.

Substrate drenches of CYC promoted new shoot development by all tested woody landscape shrub species during production, except for southern magnolia in 2005 and spreading yew in 2006. Among the responsive species, optimal concentrations for promoting shoot formation while minimizing or avoiding plant injury varied widely. In the first two experiments when plants were drenched with 50 to 1000 ppm and 25 to 100 ppm CYC, respectively, injury ratings generally increased linearly with increasing concentration, whereas shoot counts changed quadratically with the most shoots usually developing on plants drenched with a concentration other than the highest. These trends indicated that in most cases, the highest concentrations applied in the first two experiments were excessive. 'Sky Pencil' holly and 'Firepower' nandina were the exceptions, with shoot counts increasing linearly as concentration increased. However, these increases in shoots produced by 'Firepower' nandina were evident only in the year after CYC was applied, and plants drenched with 1000 ppm CYC appeared stunted. Linear increases in shoot counts and quality ratings of 'Sky Pencil' holly and 'Snow White' Indian hawthorn in the third experiment with only transitory adverse effects on plant foliage indicated optimal ranges for drench-applied CYC to these two species was probably 30 to 40 ppm. However, Indian hawthorn was more likely than 'Sky Pencil' holly to be injured by the same CYC concentration, which concured with results of foliar-applied CYC (7).

As with foliar applications of CYC (1, 6, 7), drench applications of CYC increased shoot counts of responsive species without the loss of plant biomass associated with pruning, potentially decreasing the time to sale and the labor required to produce a marketable plant canopy (1, 6, 7). However, multiple spray applications may be required to illicit the same response as a single drench application, as seen by the increased shoot counts in the spring following drench application the previous summer. Results from this study indicated that drench application of CYC is a viable alternative to spray application; however, optimal concentrations are species dependent, and potential short- or long-term adverse effects on plant appearance are a consequence from application of higher concentrations.

Literature Cited

1. Banko, T.J. and M.A. Stefani. 2007. Cyclanilide promotes lateral branching in nursery production of landscape species. J. Environ. Hort. 25:215–220.

2. Basra, A. 2007. Plant Growth Regulators in Agriculture and Horticulture: Their Role and Commercial Uses. Haworth Press, Binghamton, NY.

3. Cline, M.G. 1997. Concepts and terminology of apical dominance. Amer. J. Bot. 84:1064–1069.

4. Elfving, D.C. and D.B. Visser. 2005. Cyclanilide induces lateral branching in apple trees. HortScience 40:119–122.

5. Elfving, D.C. and D.B. Visser. 2006. Cyclanilide induces lateral branching in sweet cherry trees. HortScience 41:149–153.

6. Holland, A.S., G.J. Keever, J.R. Kessler, Jr., and F. Dane. 2007. Single cyclanilide applications promote branching of woody ornamentals. J. Environ. Hort. 25:139–144.

7. 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.

8. Holland, A.S., G.J. Keever, J.R. Kessler, Jr., and F. Dane. 2008. Interactive effects of pruning and cyclanilide application on growth of woody nursery species. J. Environ. Hort. 26:115–122.

9. Keever, G.J. and W.J. Foster. 1990. Chemically induced branching of woody landscape plants. J. Environ. Hort. 8:78–82.

10. Keever, G.J. and D.A. Findley. 2002. Thidiazuron increases shoot production in nandina. J. Environ. Hort. 20:24–28.

11. Pedersen, M.K., J.D. Burton, and H.D. Coble. 2006. Effect of cyclanilide, ethephon, auxin transport inhibitors and temperature on whole plant defoliation. Crop Sci. 46:1666–1672.

12. Runkle, E. 2007. Technically speaking: PGR drench guidelines. Greenhouse Product News 17(4):70.

13. VanderWoude, S. 2002. Early pruning equals more dollars. Nursery Management and Production 18(6):57–58.

Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-07-18 via free access