Cyclanilide Alterations In Growth Of Five Landscape Plant Species During Container Production Are Location Specific[1]

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Abstract

Five species of tropical and warm temperate shrubs, bush morning glory (*Ipomoea carnea* N. von Jacquin subsp. *fistulosa* (K. von Martinus *ex* J. Choisy) D. Austin), Indian hawthorn (*Raphiolepis indica* (L.) J. Lindley), tropical hibiscus (*Hibiscus rosa-sinensis* L. 'Brilliantissima'), jatropha (*Jatropha integerrima* N. von Jacquin), and nandina (*Nandina domestica* C.P. Thunberg), were grown in 2.8-liter (#1) black plastic containers at two contrasting nursery locations and regimes. In College Station, TX, plants were grown in full sun under high fertility conditions, while in Dallas, TX, plants were grown under 40% light exclusion and a lower fertility level. Plants at each location were sprayed to runoff, either once or twice, with a distilled water only control, a Latron B-1956 spreader sticker surfactant at 0.063 mg/liter (0.063 ppm) in distilled water, or cyclanilide [1-(2,4-dichlorophenyaminocarbonyl)-cyclopropane carboxylic acid] at 56, 112, or 223 mg/liter (56, 112, or 223 ppm, respectively) with the Latron surfactant in a distilled water carrier. Half of the plants in all treatments received a single application, while the other half received a second application two to three weeks later. Although growth responses and release of dormancy varied among species and with cyclanilide concentration, plants of most species had greater release of lateral buds from a dormant or quiescent state under the high irradiance and fertility conditions in College Station, compared to the lower irradiance and fertility conditions in Dallas. However, phytotoxicity symptoms as evidenced by lower quality ratings were also more prevalent in College Station. Phytotoxicity was moderate to severe on nearly all jatropha and tropical hibiscus plants exposed to cyclanilide. Toxicity symptoms and significant growth reductions were present on several species at 112 or 223 mg/liter (112 or 223 ppm, respectively). A second application usually increased the effects on growth responses at all concentrations and often induced phytotoxicity symptoms at 56 mg/liter (56 ppm). The disparate responses between the two locations suggest the importance of local growing conditions on the potential efficacy and predictability of responses to cyclanilide applications.

Index words: branching, bud dormancy, container nursery production, internode elongation, plant growth regulators.

Plant growth regulators used in this study: cycanilide [1-(2, 4-dichlorophenyaminocarbonyl)-cyclopropane carboxylic acid].

Species used in this study: bush morning glory (*Ipomoea carnea* N. von Jacquin subsp. *fistulosa* (K. von Martinus *ex* J. Choisy) D. Austin), Indian hawthorn (*Raphiolepis indica* (L.) J. Lindley), tropical hibiscus (*Hibiscus rosa-sinensis* L. 'Brilliantissima'), jatropha (*Jatropha integerrima* N. von Jacquin), nandina (*Nandina domestica* C.P. Thunberg).

Significance to the Nursery Industry

A well branched dense canopy of foliage is usually needed in order for tropical annuals or temperate climate shrubs in containers to appeal to consumers. This is particularly a concern on species with a tendency for minimal branching such as nandina, bush morning glory, and some cultivars of Indian hawthorn. Market appeal of other species may be improved by the induction of additional branching as it may be associated with increased numbers of flowering branches, such as on jatropha or tropical hibiscus. Reports of increased branching in response to applications of cyclanilide on fruit trees (2, 3) suggested that this compound might be useful in inducing release of lateral buds of ornamental species grown in container nurseries. Cyclanilide promoted branching on four of five species tested, but this came with a substantial risk of phytotoxicity. Growth and flowering responses were generally enhanced by high light and fertility, but this also was accompanied by increased phytotoxicity symptoms. Results of this work emphasize the need for on-site testing prior to implementation of generalized label recommendations.

Introduction

The key processes of interest to growers in ornamentals are plant height regulation, flowering, propagation of cuttings, increased branching, enhanced post harvest performance and longevity during shipping and marketing, and improved stress tolerances. Since the discovery of auxins in the 1930s, a plethora of plant growth regulators (PGRs) have been used in many crops, including bedding and potted plants, to manipulate the shape, size, form and aesthetic quality, and to strike a balance between quality and compactness to suit containers and shipping carts (5, 6, 7, 9). However, it appears that the use of PGRs in production of nursery crops and landscape plants is often limited because of inconsistent species specific responses, cost effectiveness, limited numbers of labeled compounds, constraints of uncontrolled environment and variable cultural practices.

Since the induction of additional branching may be associated with increased flowering branches in container grown tropical annuals or temperate climate shrubs, a well branched dense canopy of foliage generally appeals to consumers and enhances market value. In the past, many PGRs such as Florel and Attrimmec have been used to enhance branching, but the response has been variable, and in some plants even toxic (6, 7). In some species, gibberellins and cytokinins, alone and in

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products based on their combination (e.g., Promalin, Fascination) have shown promise in induction of additional branching (2, 3, 7), but the effects appear to be cultivar specific.

Recently, a new PGR, cyclanilide (Bayer Environmental Science, Research Triangle Park, NC) has been shown to be quite effective for induction of lateral shoot development in nursery apple, *Malus* x *domestica* M.B. Borkhauson, and sweet cherry trees, *Prunus avium* L. (2, 3). Further, in these species, by appropriate timing of cyclanilide application in relation to nursery tree height, it is also possible to obtain a desired lateral branch height (4).

The objective of these studies was to determine the potential effects of a range of cyclanilide spray applications on five species of commonly produced tropical and warm temperature climate shrubs during container production, to determine the effect of single vs double applications, and to compare the stability of responses of these species during production at two contrasting locations.

Materials and Methods

Bush morning glory (May 1, 2006; liners obtained from Petersons, San Antonio, TX), jatropha (May 1, 2006; Hines Horticulture, Houston, TX), and tropical hibiscus, Indian hawthorn, and nandina (May 2, 2006; Greenleaf Nursery, El Campo, TX) were potted in 1# (2.8-liter) black plastic containers (T1G Squat TL, Dillen Industries, Middlefield, OH) filled with Metro Mix 200 (Sun Gro Horticulture, Bellevue, WA) at the Texas A&M University Nursery/Floral Field Laboratory in College Station, TX (lat. 30°60'44'N long. 96°31'22'W). Half of the plants were transported on May 2, 2006, to the Texas A&M University Research and Extension Center in Dallas, TX (lat. 32°59'3'N long. 96°45'9'W). Plants were potted in the same medium and containers as above on May 3, 2006. Nursery conditions vary among growers in our region, thus the Dallas site was chosen to represent a lower irradiance and fertility production environment, while College Station represents a higher irradiance and fertility regime. Water quality and irrigation methods also vary among production facilities and were approximated by using overhead delivery in Dallas and subcanopy delivery at College Station.

In College Station the container substrate was amended with 6.8 kg/m^3 (12 lb/yd^3) of 18N–3P–8.3K controlled release fertilizer (18–7–10, Scotts Corp., Marysville, OH), 3.4 kg/m^3 (6 lb/yd^3) of dolomite (Vulcan Materials Co., Tarrant, AL), 1.7 kg/m^3 (3 lb/yd^3) gypsum (Standard Gypsum Corp., Fredericksburg, TX), and 0.68 kg/m^3 (1.5 lb/yd^3) Micromax micronutrients (Scotts Corp.). After transplanting, fifty plants each of the five species were placed in an outdoor nursery on a graveled surface in full sun. The plants were hand irrigated using water which was injected with concentrated sulfuric acid (H_2SO_4, Hadros Corp., Pasadena, TX) to lower water pH to a target of 6.5 and with 50 mg/liter (50 ppm) N from a 24N–3.5P–13.2K (24–8–16, 7.19% ammonium nitrate, 7.21% urea, and 9.60% nitrate, Scotts Co., Marysville, OH) water soluble fertilizer. Plants at the College Station site received supplemental fertigations containing 50 mg/liter (50 ppm) each of Fe (Sprint 138, Becker Underwood, Ames, IA), Ca ($CaSO_4{\cdot}H_2O$, United States Gypsum Co., Chicago, IL), and Mg ($MgSO_4$, Giles Chemical Corp., Waynesville, NC) on June 23, 2006, and July 12, 2006.

In Dallas, the substrate was amended with 5 g per container (equivalent to 8.8 lb/yd^3) of Osmocote (14N–6.1P–11.6K, Scotts Corp.) after transplanting. Fifty plants each of the five species were placed in an outdoor structure covered with shade cloth reducing light by 40% on a gravel floor covered with black weed fabric. Plants were irrigated daily with an automated overhead irrigation system and fertigated by hand once a week with 200 mg/liter (200 ppm) N from a 20N–8.75P–16.5K (20–20–20, 3.94% ammonium nitrate, 10.01% urea, and 6.05 % nitrate, Scotts Corp.) general purpose water soluble fertilizer.

Each species was arranged in both nurseries in a completely randomized design containing factorial combinations of the two application times and five plant growth regulator treatments. On May 9, 2006, ten jatropha and ten bush morning glories were temporarily moved indoors and sprayed to runoff with one of five plant growth regulator treatments: a distilled water only control, a Latron B-1956 spreader sticker surfactant (modified phthalic glycerol alkyd resin, Loveland Industries, Inc., Greeley, CO) alone at 0.063 mg/liter (0.063 ppm) in distilled water, or cyclanilide (Bayer Environmental Science) at 56, 112, or 223 mg/liter (56, 112, or 223 ppm, respectively) with Latron B-1956 in a distilled water carrier. After the foliage dried, plants were returned to the nursery. On May 10, 2006, tropical hibiscus, Indian hawthorn, and nandina plants received the same treatments. On May 23, 2006, half of the bush morning glory receiving each of the initial treatments received a second dose of the same treatment. On May 29, 2006, the process was repeated with the other four species.

When plants were potted, initial data was collected for plant height, canopy spread in two perpendicular directions, the number of buds that exhibited expanding leaves at nodes on the main stems, and the number of inflorescences with open flowers. Final growth data and quality ratings were assigned when the majority of the control plants reached a marketable size. Growth parameters were those as indicated for the initial measurements, plus shoot and root dry masses. Bush morning glory plants were harvested on June 2, 2006, jatropha and tropical hibiscus on June 21, 2006, nandina on July 20, 2006, and Indian hawthorn on August 3, 2006. A pseudo-volumetric plant index was calculated for plants by multiplying the height × the canopy spread in two directions. Changes in this index were obtained by subtracting the same measure calculated based on plant size at initiation of the study. Change in the number of nodes with elongating buds was calculated by subtracting the ending number from that at the beginning of the study. Total plant dry weight was determined by addition of root and shoot dry weights. Root-to-shoot dry weight ratios were determined by dividing the root dry weight by the shoot dry weight.

Quality ratings were determined on a zero to five scale. These incorporated such factors as canopy density, vigor, flower number, and severity of phytotoxic symptoms if present. A zero was assigned to plants that were dead at the end of the study. Generally, a one represented a plant that was a definite cull in some manner due to poor growth or severe toxicity symptoms, including mild to severe defoliation, or chlorosis or necrosis of the foliage. A two represented marginal plants that were generally substandard and would not typically be deemed marketable due to one or more significant defects or poor vigor, but which might recover from mild toxicities or reach a marketable size with more time in production. Plants rated a three were those deemed to be at or slightly above a minimal marketable size and quality, but

Table 1. Three-way interactions among location, number of applications, and cyclanilide treatments on growth of five landscapes species, n = 5.

			Bush morning glory	Tropical hibiscus			Jatropha		Indian hawthorn	
Location	Spray applications	Cyclanilide treatments	root-to-shoot dry weight (mg/mg)	Plant index (Δ cm³)[z]	Shoot dry weight (mg)	Total plant dry weight (mg)	Shoot dry weight (mg)	Total plant dry weight (mg)	Root dry weight (mg)	Root-to-shoot dry weight (mg/mg)
College Station	Once	Water only	0.35efg[y]	46733b	16.1abc	20.6ab	9.5a	10.9a	4.2bc	0.27bcd
		Surfactant only	0.38ef	42178bc	16.6ab	21.4a	7.3ab	8.6abc	1.7de	0.06e
		56 mg/liter Cyc.	0.34fg	31170cdef	15.0bcd	19.2ab	5.6bcde	6.7cdef	6.9a	0.35ab
		112 mg/liter Cyc.	0.28g	33697bcd	16.3abc	20.5ab	3.1fghij	3.6ghi	1.7de	0.10e
		223 mg/liter Cyc.	0.31fg	26358defgh	18.6a	22.7a	5.1bcdef	5.8defg	7.0a	0.41a
	Twice	Water only	0.37ef	69573a	19.6a	23.6a	9.0a	10.5ab	4.9abc	0.10e
		Surfactant only	0.37ef	41446bc	16.5ab	20.1ab	9.4a	10.9a	1.1e	0.25bcd
		56 mg/liter Cyc.	0.33fg	16509hij	11.8def	14.2cde	6.2bcd	6.9cdef	4.3bc	0.25bcd
		112 mg/liter Cyc.	0.33fg	12561ij	9.0efg	10.8ef	1.7ij	2.1i	4.7bc	0.27bcd
		223 mg/liter Cyc.	0.31fg	8193j	7.9g	9.5f	1.3j	1.6i	1.2e	0.11e
Dallas	Once	Water only	0.64b	29502defg	11.3efg	16.6bc	4.8cdef	6.4cdef	5.1abc	0.32abcd
		Surfactant only	0.61b	32434cde	11.0efg	15.7bcd	6.4bc	8.2bcd	6.1ab	0.33abc
		56 mg/liter Cyc.	0.62b	19629fghij	9.5efg	13.1cdef	3.9defghi	5.1efgh	4.4bc	0.27bcd
		112 mg/liter Cyc.	0.57bc	18677ghij	10.3efg	14.4cde	4.1defgh	5.5efg	4.5bc	0.27bcd
		223 mg/liter Cyc.	0.38ef	37941bcd	12.3cde	16.2bc	3.7efghi	4.9fgh	3.5cd	0.24cd
	Twice	Water only	0.74a	27596defgh	11.1efg	16.0bc	5.8bcde	7.7cde	4.5bc	0.31abcd
		Surfactant only	0.50cd	26416defgh	9.9efg	13.1cdef	4.4cdef	5.8defg	4.6bc	0.33abc
		56 mg/liter Cyc.	0.40ef	19840fghij	10.0efg	14.2cde	1.9hij	2.8hi	4.7bc	0.33abcd
		112 mg/liter Cyc.	0.37efg	21228efghi	9.9efg	13.6cdef	4.1cdefg	5.2fgh	4.3bc	0.28bcd
		223 mg/liter Cyc.	0.43de	11247ij	8.6fg	11.4def	1.9ghij	2.7hi	3.2cde	0.22d

[z]Mean change in plant size calculated by subtracting initial plant size index from final plant size index.

[y]Means within a column followed by the same letter are not significantly different at $P \leq 0.05$ using least squares means comparisons.

possessing some minor defects or minor toxicity symptoms in the foliage. A rating of four indicated plants that significantly exceeded minimum standards for a marketable size and quality, possessing few if any defects and having large robust canopies. Plants rated a five were those deemed to be truly outstanding and which far exceeded minimum market quality standards, possessed vigorous defect free canopies and excellent growth form.

Quantitative data from each species was analyzed as a complete factorial consisting of two locations × two applications × five cyclanilide treatments (including the water and surfactant controls and three levels of plant growth regulator) × five replicates per treatment combination (100 total plants for each species). Each species was maintained as a separate experiment in the nurseries, but were conducted concurrently. Least squares means procedures in SAS (version 9.1, SAS Institute, Cary, NC) were used to compare means for those effects in which the highest order interaction or main effect was significant ($P \leq 0.05$) in the analysis of variance for each quantitative variable. Quality rating data were analyzed for normality. The results of the Kolomograv-Smirnov test indicated a violation of the assumption of normality for the data set ($P \leq 0.005$), thus Chi-square analysis of the data were performed.

Results and Discussion

For all species, where significant ($p \leq 0.05$), higher order interactions were presented for each measured characteristic (Table 1). Lower order interactions or main effects are presented for characteristics which did not have significant higher order interactions (Tables 2, 3, 4, 5).

Bush morning glory. The only parameter to exhibit a three-way interaction in bush morning glory was for the root-to-shoot dry weight ratios (Table 1). Root-to-shoot ratios were generally lower in College Station than in Dallas for bush morning glory plants (Table 1), apparently due to larger shoot dry weights in College Station (14.5 vs 9.6 mg) which constituted the largest portion of total plant dry weights (19.5 vs 14.8 mg). Cyclanilide treatments had very little effect on bush morning glory root-to-shoot ratios in College Station, but

Table 2. Two-way interactions among location and number of spray applications of cyclanilide on growth of three species, n = 25.

Location	Spray applications	Bush morning glory plant index (Δ cm³)	Tropical hibiscus root dry weight (mg)	Indian hawthorn branches (Δ #/plant)
College Station	Once	32606b[z]	4.4a	14.0b
	Twice	22001c	2.7b	24.4a
Dallas	Once	46982a	4.3a	5.8c
	Twice	50909a	3.7a	7.5c

[z]Means within a column followed by the same letter are not significantly different at $P \leq 0.05$ using least squares means comparisons.

Table 3. Two-way interactions among locations and cyclanilide treatments on growth and flowering of five landscape species, n = 10.

Location	Cyclanilide treatments	Bush morning glory Plant index (Δ cm³)	Bush morning glory Branches (Δ #/plant)	Tropical hibiscus flower number (#/plant)	Jatropha Plant index (Δ cm³)	Jatropha Root dry weight (mg)	Indian hawthorn Plant index (Δ cm³)	Indian hawthorn Branches (Δ #/plant)	Nandina Plant index (Δ #/plant)	Nandina Root dry weight (mg)	Nandina Shoot dry weight (mg)	Nandina Total plant dry weight (mg)
College Station	Water only	37238bc[z]	8. bcd	8.7a	18553a	1.5bc	10634ab	4.7ef	24419a	4.2a	12.7a	16.9a
	Surfactant only	40596b	9.3bcd	6.2ab	16427ab	1.4bc	11561a	4.9ef	25965a	3.3b	11.7a	15.0a
	56 mg/liter Cyc.	24862cd	18.8a	3.7bcd	12953bc	0.9e	8299b	18.7c	7960cde	1.6de	6.1b	7.7b
	112 mg/liter Cyc.	14603d	10.3bc	3.6cde	2453f	0.5f	9241ab	29.3b	5539de	1.5de	5.3bc	6.8bc
	223 mg/liter Cyc.	19219d	12.6b	4.5bc	3044f	0.5f	4314c	38.4a	3707e	1.1e	4.0c	5.1c
Dallas	Water only	50401ab	1.0f	0.9f	11624cd	1.8a	8948ab	2.1f	15019b	2.6bc	4.3bc	6.9bc
	Surfactant only	54634a	0.4f	1.1ef	10993cd	1.6ab	9647ab	2.6f	10155bcd	2.2cd	3.9c	6.1bc
	56 mg/liter Cyc.	40537b	3.9ef	0.8f	5099ef	1.1de	10647ab	5.3ef	12289bc	2.1cd	4.1c	6.2bc
	112 mg/liter Cyc.	53239ab	5.7de	1.0f	8256de	1.2cd	9557ab	10.4de	12592bc	1.9cde	3.9c	5.8bc
	223 mg/liter Cyc.	45918ab	7.1cde	1.2def	3030f	1.0de	8490b	12.8cd	9661bcde	2.2cd	4.1c	6.3bc

[z]Means within a column followed by the same letter are not significantly different at $P \leq 0.05$ using least squares means comparisons.

decreased with increasing concentrations of cyclanilide at the Dallas location (Table 1). Although bush morning glory plants in Dallas generally had a greater plant index than those in College Station (Table 2), they were less responsive to the cyclanilide treatments as evidenced by a less substantial effect on change in plant index in Dallas (Table 3). The total number of buds elongating were greater in College Station than in Dallas but cyclanilide induced increases in the number of branches of bush morning glory at both locations (Table 3). A single medium to high concentration of cyclanilide or two applications of the low rate of cyclanilide induced the greatest number of elongating new branches (Table 4). Across locations and concentrations, double applications of cyclanilide reduced total plant, shoot, and root dry weights (15.9, 11.2, and 4.7 mg per plant, respectively) in comparison to single applications (18.4, 13.0, and 5.4 mg per plant, respectively). Flowering was sparse in Dallas (1.0 flower per plant), and nonexistent in College Station (0 flowers per plant) during the test. Bush morning glory plants grown in full sun and high fertility conditions in College Station were more compact and had increased bud elongation, particularly at the 112 and 223 mg/liter (112 and 223 ppm) concentrations (Tables 2 and 3).

Prior work has demonstrated that cyclanilide releases lateral buds from apical dominance (2, 3), likely by interfering with auxin transport and action (8). One explanation for the greater branching and lateral bud elongation in College Station is that the higher light and fertility regimes may have promoted greater shoot elongation of lateral buds when released from apical dominance by the cyclanilide treatments compared to the lower light and lesser fertility conditions in Dallas. Bush morning glory treated in Dallas exhibited marginal quality improvement, whereas in College Station only the single application of 56 or 112 mg/liter (56 or 112 ppm) improved quality ratings (Fig. 1A, B). With double applications of cyclanilide or a single 223 mg/liter (223 ppm) application in College Station, quality ratings were reduced due to toxicity (Fig. 1A, B).

Tropical hibiscus. Change in plant index, shoot dry weight and total plant dry weight all exhibited significant three-way interactions ($P \leq 0.05$) with tropical hibiscus (Table 1). Water and surfactant controls were larger at College Station than at Dallas for all three measures (Table 1), but in many cases cyclanilide treatments resulted in reductions in plant indices for tropical hibiscus in College Station. These reductions were more pronounced with two rather than a single application. Consistency of tropical hibiscus shoot and total plant dry weight responses to cylandilide applications were less predictable, but tended to follow a similar pattern as seen for plant indices (Table 1). Tropical hibiscus branched more extensively with increasing concentrations of cyclanilide (Table 5), in College Station than in Dallas (12.0 vs 3.6 branches per plant), and with two cyclanilide applications (15.9 branches per plant) rather than a single application (12.0 branches per plant). Root dry weight responses for tropical hibiscus were more straight forward with root dry weight generally declining with increasing cyclanilide levels (Table 5), particularly in College Station with two applications times (Table 2). Lateral branching was much greater for tropical hibiscus in the full sun high fertility conditions in College Station, but root-to-shoot dry weights were reduced (Table 5). Only the highest rate of cyclanilide reduced tropical hi-

Table 4. **Two-way interactions among spray applications and cyclanilide treatments on growth and flowering of five landscape species, n = 10.**

Spray applications	Cyclanilide treatments	Bush morning glory branches (Δ #/plant)	Tropical hibiscus flower number (#/plant)	Jatropha Plant index (Δ cm^3)	Jatropha Flower number (#/plant)	Indian hawthorn Plant index (Δ cm^3)	Indian hawthorn Branches (Δ #/plant)
Once	Water only	5.7cd[z]	3.6abc	14930a	3.1a	9931abc	3.5e
	Surfactant only	5.6cd	4.3ab	12397a	2.5ab	11995a	3.5e
	56 mg/liter Cyc.	9.9ab	3.1bcd	11102ab	2.7a	8543bcde	10.4d
	112 mg/liter Cyc.	11.1ab	4.0ab	5860c	2.6a	11456a	14.0cd
	223 mg/liter Cyc.	10.7ab	5.1ab	6355c	4.2a	7010de	18.2c
Twice	Water only	4.2d	6.0a	15248a	3.0a	9652abcd	3.3e
	Surfactant only	4.1d	3.0bcd	15023a	2.5ab	9213abcd	4.0e
	56 mg/liter Cyc.	12.8a	1.4cd	6949bc	3.1a	10402ab	13.8cd
	112 mg/liter Cyc.	4.9d	0.6d	4848c	0.6c	7342cde	25.7b
	223 mg/liter Cyc.	9.0bc	0.6d	–281d	0.7bc	5794e	33.0a

[z]Means within a column followed by the same letter are not significantly different at $P \leq 0.05$ using least squares means comparisons.

biscus root-to-shoot ratios across locations (College Station 0.24 vs 0.30 at Dallas) and a second application of cyclandilide (0.29) reducing root-to-shoot ratios compared to a single application (0.34). Although flowering of tropical hibiscus was less affected by a single application of cylcanilide than two applications (Table 4), this was moderated by greater flowering responses in College Station than in Dallas (Table 3). Tropical hibiscus produced few flowers regardless of cyclanilide treatment in Dallas, while in College Station many more flowers were produced, but cylanilide generally reduced the flower number (Table 3). A single application at all tested concentrations of cyclanilide in College Station or at 223 mg/liter (223 ppm) in Dallas improved quality ratings, but two applications reduced quality ratings at both locations regardless of concentration (Fig. 1C, D).

Jatropha. Significant three-way interactions were found for jatropha for shoot and total plant dry weights (Table 1). Jatropha tended to be larger in shoot and total plant dry weights in College Station than Dallas, but increasing rates and number of applications of cyclanilide resulted in more pronounced reductions in biomass measures in College Station than Dallas (Table 1). Across locations and concentrations, double applications of cyclanilide significantly, although slightly, reduced root dry weight (1.1 vs 1.2 mg per plant). This was likely due to the strong tendency for cyclanilide applications to cause partial or complete defoliation of jatropha at the tested rates in College Station. Despite this defoliation, jatropha in College Station began to recover at lower rates and the cyclanilide did result in a greater increase in branching (6.6 vs 2.2 branches per plant) and flowering (3.7 vs 1.3 flowers per plant) in College Station than in Dallas. In fact, on average across locations and number of applications, branching increased at any of the three cyclanilide rates tested (Table 5). However, the decreased growth in plant index (Tables 3 and 4) and total dry weight (Table 1), along with the foliar symptoms of phytotoxicity would likely render most of the cyclanilide treated jatropha commercially unacceptable, despite the improved branching. The root-to-shoot ratios of jatropha were significantly lower in College Station than in Dallas (0.21 vs 0.39), primarily due to much greater shoot dry mass of water only and surfactant treated plants in College Station than Dallas (Table 3), rather than the more modest differences in root dry weight (Table 3). While jatropha tolerates both sun and moderate shade conditions, its shoot growth is more vigorous in full sun (1). Quality ratings for water only and surfactant treated plants were higher in College Station than in Dallas (Fig. 1E, F). However, all cyclanilide applications, except for the single application of 56 mg/liter (56 ppm), reduced jatropha quality ratings in comparison to the water and surfactant controls at College Station.

Indian hawthorn. Three-way interactions were present for Indian hawthorn only for root dry weights and root-to-shoot dry weights (Table 1). Root dry weights of Indian hawthorn were largely unaffected by cyclanilide treatments in Dallas, but root dry weights were rather unpredictably increased or decreased by various concentrations of cyclanilide in College Station (Table 1). This resulted in similar unpredictability

Table 5. **Main effects of the cyclanilide treatments on growth and flowering of five landscape species, n = 20.**

Cyclanilide treatments	Bush morning glory Root dry weight (mg)	Bush morning glory Total plant dry weight (mg)	Tropical hibiscus Branches (Δ #/plant)	Tropical hibiscus Root dry weight (mg)	Tropical hibiscus Root to shoot dry weight (mg/mg)	Jatropha branches (Δ #/plant)	Indian hawthorn flower number (#/plant)
Water only	6.8a[z]	20.2a	10.1c	4.7a	0.36a	2.2b	0.7a
Surfactant only	5.9a	19.1a	11.5bc	4.1ab	0.31ab	2.3b	0.5a
56 mg/liter Cyc.	4.7b	16.4b	15.6ab	3.6bc	0.33a	5.9a	0.0b
112 mg/liter Cyc.	4.2b	15.5bc	15.1ab	3.4bc	0.31ab	5.4a	0.1b
223 mg/liter Cyc.	3.7b	14.4c	17.3a	3.1c	0.27b	6.4a	0.0b

[z]Means within a column followed by the same letter are not significantly different at $P \leq 0.05$ using least squares means comparisons.

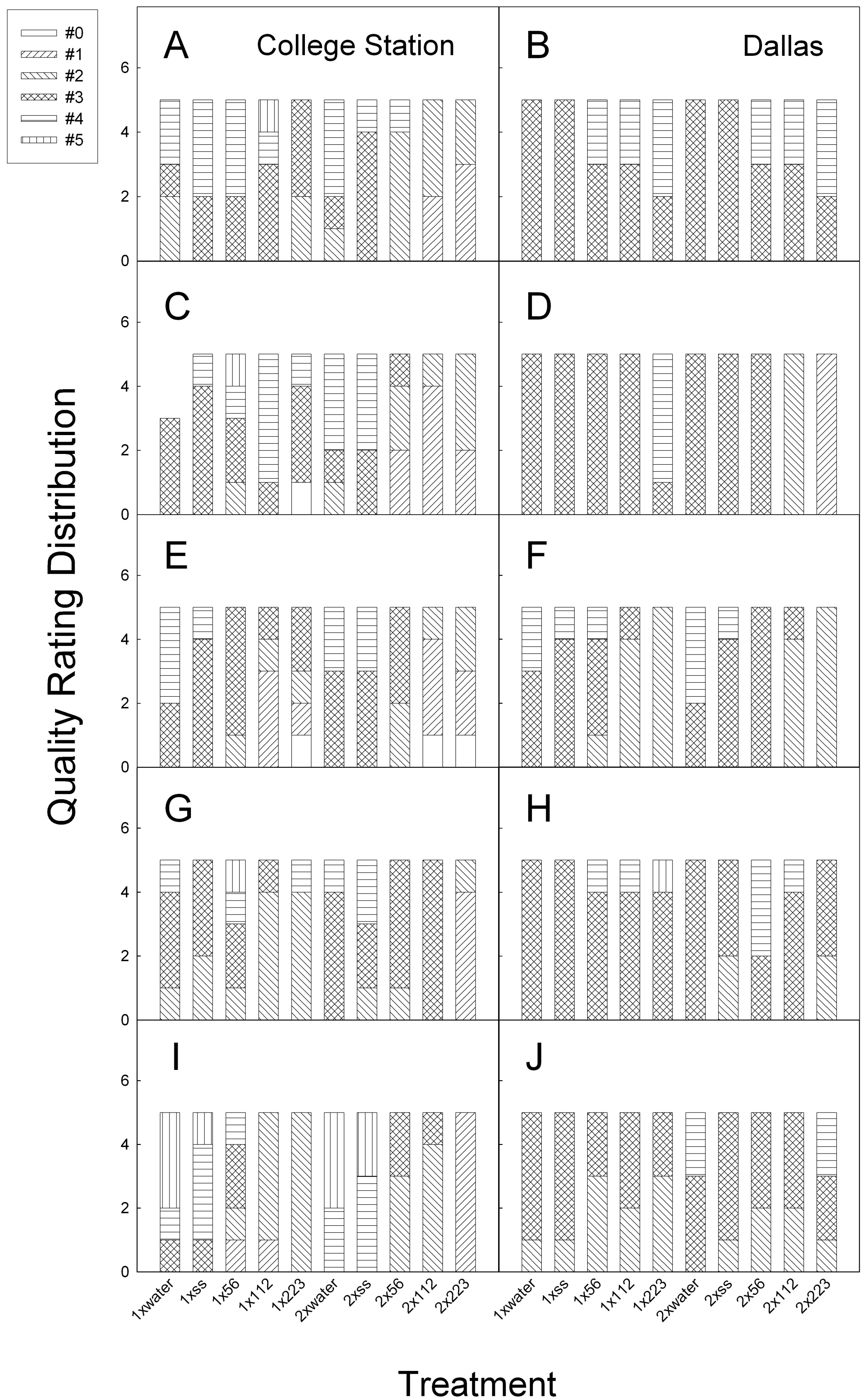

Fig. 1. Distribution of quality ratings for bush morning glory (A, B), tropical hibiscus (C, D), jatropha (E, F), Indian hawthorn (G, H) and nandina (I, J). Chi square probability values are: A ($P \leq 0.01$); B ($P \leq 0.1$); C (P ≤ 0.005); D ($P \leq 0.001$); E ($P \leq 0.05$); F ($P \leq 0.001$); G ($P \leq 0.001$); H ($P \leq 0.05$); I ($P \leq 0.001$); J ($P \leq 0.1$). Single applications of water only, latron only (SS), 56, 112 or 223 ppm cyclanilide are denoted by 1x and double applications of the same materials are denoted by 2×.

of response to cyclanilide on root-to-shoot ratios on plants grown in College Station compared to Dallas, where root-to-shoot ratios of Indian hawthorn decreased at the highest cyclanilide concentrations (Table 1). Shoot dry weight was significantly greater in College Station than in Dallas (17.0 mg vs 15.5 mg) and with a single compared to double applications of cyclanilide (17.1 mg vs 15.5 mg). When averaged across application times, Indian hawthorn plant indices were reduced by single or double applications of cyclanilide at 223 mg/liter (223 ppm) (Table 4), with a more pronounced effect in College Station (Table 3). Although as indicated by plant indices, the plant canopies of Indian hawthorn were smaller with cylanilide applications, they also were more densely branched (Table 3). This effect was more pronounced in College Station under high light and fertility (Tables 2 and 3) and with double rather than single cyclanilide applications (Tables 2 and 4). Although cyclanilide statistically reduced flowering of Indian hawthorn, total flowering of Indian hawthorn was very low in all treatments due to the season. Indian hawthorn typically blooms in spring (1) rather than summer when these plants were harvested. Quality ratings were minimally impacted at both locations, except at the highest rate which reduced quality ratings, more severely so in College Station due to the development of greater phytotoxicity (Fig. 1G, H).

Nandina. Nandina did not exhibit any significant three-way interactions. Plant index, and root, shoot, and total plant dry mass of nandina were reduced by increasing cyclanilide applications in College Station, but to a much less extent in Dallas (Table 3). Nandina plant index was significantly reduced more by two cylcanilide applications than one (13,518 cm^3 for a single application vs 11,943 cm^3 for two applications) and root-to-shoot dry weights were substantially smaller in College Station than in Dallas (0.31 vs 0.59). Cylanilide had no significant ($P \leq 0.05$) effects on branching or flower number in nandina (data not presented). There was no enhancement of nandina quality ratings by the cyclanilide treatments at either location (Fig. 1I, J).

Cyclanilide was effective in promoting branching on all species tested, except nandina. This appears to be consistent with published reports on species grown in cool temperate climates (2, 3, 4). However, this often came at the cost of decreases in plant growth or the induction of foliar phytotoxicity symptoms. Cyclanilide appeared to be most effective in promoting branching under the greater light and fertility conditions in College Station compared to Dallas, suggesting that rapid growth conditions are needed for effective release of lateral buds. This would suggest testing of cylcanilide under lower light or fertility production regimes prior to widespread use. It would appear that responses to cyclanilide are not consistent across production conditions or species. Phytotoxicity was noted on all species, except nandina, although most plants tended to recover over time. In addition, it appears that phytotoxicity risk is greater on material that is less woody and unfortunately the risks of foliar toxicity appeared to be much greater under the high light and fertility conditions in College Station where cylcanilide was most effective at inducing additional branching.

Literature Cited

1. Arnold, M.A. 2002. Landscape Plants for Texas and Environs, 2nd ed. Stipes Publ. Champaign, IL. p. 1088.

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

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

4. Elfving, D.C. and D.B. Visser. 2006b. Timing cyclanilide and cytokinin applications in the nursery to obtain desired lateral branch height in apple and sweet cherry trees. HortScience 41:1238–1242.

5. Fletcher, R.A., A. Gilley, N. Sankhla, and T.D. Davis. 2000. Triazoles as plant growth regulators and stress protectants. Hort. Rev. 24:55–138.

6. Keever, G.J. 1997. Plant growth regulators for production and maintenance of woody and herbaceous plants. Proc. Amer. Soc. Plant Growth Regul. 24:152–154.

7. Latimer, J.G. 2004. Trends and uses of plant growth regulators on herbaceous perennials. Proc. Amer. Soc. Plant Growth Regul. 31:1–4.

8. Pederson, M.K., J.D. Burton, H.D. Coble, J.R. Collins, and D. Fritz. 1997. Efficacy of Finish and its mechanism of action. Proc. Beltwide Cotton Conf. 2:1363–1365.

9. Rademacher, W. 2004. Recent situation and trends in global plant bioregulator utilization. Regul. Plant Growth Devel. 39:142–151.