HRI's Mission:

To direct, fund, promote and communicate horticultural research, which increases the quality and value of ornamental plants, improves the productivity and profitability of the nursery and landscape industry, and protects and enhances the environment.

The use of any trade name in this article does not imply an endorsement of the equipment, product or process named, nor any criticism of any similar products that are not mentioned.

Cyclanilide Spray Increases Branching in Containerized Whip Production[1]

Petra Sternberg[2] and Daniel K. Struve[3]
Department of Horticulture and Crop Science
The Ohio State University, Columbus, OH 43210

Abstract

A major goal in the production of tree whips is to produce appropriately sized, well-branched liners with a crown form similar to that of a mature tree. Pruning is used to induce lateral branching. This can result in poor tree quality, reduced growth and the practice is labor intensive. An alternative to mechanical pruning, foliar Cyclanilide® (CYC) sprays at 0, 56, 112 and 223 ppm were applied to container grown whips to determine its effect on branching of A*melanchier*; *Cercis*, *Malus* and *Tilia* whips. Most species responded to CYC sprays with increased lateral branching if treated during active shoot elongation. Cyclanilide® sprays of 112 ppm produced the greatest number of branches. Sprays at 56 ppm resulted in reduced branching (relative to 112 ppm), while sprays of 223 ppm did not increase the number of branches, relative to sprays of 112 ppm, but reduced growth. Cyclanilide® sprays reduced height growth, relative to untreated whips, but did not alter height diameter growth. Cyclanilide® foliar applications to container-grown whips during periods of active shoot elongation increased branching in one-year-old whips that normally do not branch until the second year of production. Further, the origin of lateral branching can be controlled by timing of CYC application. The results indicate that CYC foliar sprays can be an important tool in the production of one-year-old branched whips.

Index words: plant growth regulator, apical dominance, apical control, excurrent species, decurrent species.

Species used in this study: Autumn blaze serviceberry, *Amelanchier* x*grandiflora* 'Autumn Blaze'; Prairie fire crabapple, *Malus x* 'Prairie Fire'; Chinese redbud, *Cercis chinensis* 'Avondale'; and Greenspire linden, *Tilia cordata* 'Greenspire'.

Chemicals used in this study: 1-[(2,4-dichlorophenylamino-carbonyl)-cyclopropane carboxylic acid] (Cyclanilide), Mixture of modified phthalic glycerol alkyd resin and butyl alcohol (Latron B-1956).

Significance to the Nursery Industry

Shade tree whips can be produced in containers. Excurrent species are especially well suited to container production because they grow rapidly and branch freely during the first year of production. However, many decurrent species, unless pruned, do not branch until the second year of production. A new chemical (Cyclanilide®, Bayer Environmental Science, Montvale, NJ) applied as a foliar spray will increase branching in the first year of production even in decurrent species. Additionally, the origin of branching can be controlled.

Introduction

Whips are small, one- or two-year-old trees approximately 12.7 to 19.1 mm (0.5 to 0.77 in) in caliper and 120 to 240 cm (3.9 to 7.9 ft) in height (1). Although whips are marketed as either branched or unbranched, there is an increased demand for branched whips. Branched whips are more popular because they shorten rotation times. Also there is a new retail market for container grown whips (11). An additional benefit of branched whips is that they command a higher price. For instance, a 1.5 to 2 m (4.9 to 6.6 ft) tall branched whip sells for about 50% more than an unbranched whip of the same height (6). The challenge is to produce small caliper whips with a dense crown, similar to the characteristic crown form of a mature tree. Thus, whips are pruned to increase the number of branches, which results in the appearance of a denser crown. The appearance of a dense crown can result from any combination of short internodes, dense foliage, increased branch density or uniform outline (2).

Branched whips of some taxa are easier to produce than others. Excurrent species have weak apical control but strong apical dominance. They have the potential to elongate lateral buds in the season of their initiation and have a narrow upright crown form (8, 13). In contrast, decurrent species have strong apical dominance, but weak apical control. Lateral buds elongate the season after their initiation and have a broad spreading crown form.

Cline (2) divided apical dominance and its release into four stages, based on differential response to hormones. In stage one, cytokinin promotes lateral bud formation. In stage two, apical dominance is imposed by auxin, produced in terminal buds and shoots. If buds enter stage three (resulting from a compromised apical meristem due to injury, removal or loss of apical dominance in excurrent species) lateral bud elongation is attributed to increased cytokinin levels. In stage four, auxin and gibberellin promote the further elongation of the lateral bud into a branch.

An additional problem in whip production is excessive height growth. Excessive height growth occurs in both field and containerized production systems and leads to whips so tall that the trunk does not support the crown (17). A good measure of whip quality is the height:caliper ratio. Nursery stock standards require a 2 to 2.5 m (6.6 to 8.2 ft) tall whip to have a caliper of at least 2 cm (0.8 in), or a height:caliper ratio of 9.6 to 12.8 (1). Whips with a higher height:caliper ratio usually require staking and are considered lower quality.

In the production of two-year-old whips, height growth is regulated and decurrent species are molded into a more excurrent growth habit, by pruning. Branching is promoted by pruning of the terminal leader in the dormant season following the first year of growth and reestablishing a central leader by training a lateral bud into an upright growth habit. Dormant season pruning is used to establish lateral branching at

[1]Received for publication May 17, 2007; in revised form July 27, 2007.
[2]Graduate Research Associate <sternberg.11@osu.edu>.
[3]Professor <struve.1@osu.edu>.

a desired height. Summer pruning is also used to increase crown density (14). However, the new growth that develops after summer pruning is more susceptible to insect damage, such as leaf hoppers (7). In floriculture crops, lateral branching is stimulated by chemical pinching agents, which removes apical dominance by destroying the shoot apex. Although chemical pinching agents are used in the production of floricultural crops, they are not used in shade tree production.

A new chemical, Cyclanilide (CYC), (Bayer Environmental Science, Montvale, NJ) significantly increased the number of lateral branches on apple and sweet cherry trees in orchard systems (3, 5). Cyclanilide interrupts apical dominance without damaging the terminal shoot apex. The mode of action is unknown, but CYC is thought to interfere either with auxin synthesis or transport (15).

Little however, is known about the affect of CYC on other woody ornamental crops, especially those outside of the Rosaceae. The purpose of this study was to determine if foliar CYC sprays could be used to increase branching in one-year-old container grown whips of taxa exhibiting either decurrent or excurrent growth habit and to investigate its effect on height and caliper growth.

Material and Methods

Four taxa, *Amelanchier* x*grandiflora* 'Autumn Blaze', *Malus* x 'Prairie Fire', *Cercis chinensis* 'Avondale' and *Tilia cordata* 'Greenspire' were used. The experiments were conducted at The Ohio State University, Columbus, OH.

All plants were received as rooted microcuttings (Microplant Nurseries, Inc., Gervais, OR) between November 23, 2005, and February 2, 2006, and were potted into 24 cell HIKO™ trays with an individual cell volume of 150 ml (9.2 cu. in.) (V150SS, Stuewe & Sons, Corvallis, OR) filled with Fafard 3B (Conrad Fafard, Inc., Agawam, MA) substrate. The plants were acclimated to greenhouse conditions over a three week period. Following acclimation, all plants received 50 mg N/liter of water soluble fertilizer (21N:3.1P:5.7K Plantex 20–10–20 High Nitrate, Plantex, LLC, Brampton, ON, Canada). Seven weeks later the plants were transplanted into black plastic containers (C-150, 10.2 square × 13 cm deep (4 × 5.1 in), 0.768 liter (0.8 qt), Nursery Supplies, Chambersburg, PA) and placed pot-to-pot on a greenhouse bench. Plants were top dressed with 3 g (0.1 oz) per container of a controlled release fertilizer (2–3 month formulation, 12N:2.2K:7.4P Top Dress Special, The Scotts Miracle-Gro Company, Marysville, OH).

On May 23, 2006, the *Malus* whips were transplanted into #3 containers (28 dia × 24 cm deep (11.0 × 9.4 in), 11.4 liter (12.1 qt), Classic 1200, Nursery Supplies, Chambersburg, PA) in a 3:1 (by vol) pine bark and Com-Til® substrate. On June 8 *Amelanchier*, *Cercis* and *Tilia* whips were transplanted as described for *Malus*. After potting all plants were placed on a gravel pad on 30 cm (1 ft) within row and 130 cm (4.3 ft) between row spacing. The experimental plot was surrounded by a guard row of plants similar to the experimental material. The experimental design for each species was a randomized complete block design with five single tree replications for *Amelanchier* and six single tree replications for *Cercis*, *Malus* and *Tilia*.

The most vigorous shoot on each plant was trained into a central leader by staking it to a 2 m (6.6 ft) tall bamboo shoot (A.M. Leonard, Inc., Pique, OH). At first staking all lateral shoots were removed (to simplify data collection). No other pruning was done for the remainder of the experiment. Each whip received 7.3 liter (7.7 qt) of irrigation per day, split into two 10 minute irrigation events (0600 and 1200 h) using Grey Mini Flow Spot Spitters (SS-AG90GRY-100, Roberts Irrigation Products, Inc., San Marcos, CA). Each container received 24 g (0.8 oz) controlled release fertilizer (eight-nine month, 19N:2.6P:10K Osmocote Classic, The Scotts Miracle-Gro Company, Marysville, OH) on June 15. Fertigation was started on July 14 using 100 mg N/liter (21N:3.1P:5.7K Plantex 20-10-20 High Nitrate) applied with a DI-16 Dosatron® (Dosatron North and Central America, Clearwater, FL).

On August 4, 2006, CYC was applied as a foliar spray at concentrations of 0, 56, 112 and 223 ppm. The spreader/sticker, Latron B-1956 (Loveland Industries Ltd., Greeley, CO) was added to the CYC sprays at 0.06% (by vol). Control whips remained unsprayed and were not treated with Latron B-1956. The whips were unbranched and in active shoot elongation at time of application. The whips were sprayed until run-off using a hand sprayer (Handy sprayer, Hudson Model number 69142). An average of 52 ml (1.8 oz) solution was applied per whip, or approximately 2.9, 5.8 or 11.6 mg a.i. for the 56, 112 and 223 ppm treatments, respectively. The weather during application was clear with 26C (79F) temperature, 60% relative humidity and a wind speed of 16 km/h (9.9 mph). Whips were treated between 1100 and 1200 HR.

Initial measurements taken before treatment included caliper, height and total number of buds on the central leader. After Cyclanilide® treatment, height was measured weekly through September. Final height and caliper measurements were taken on September 26, 2006. Additionally, the number of branches were counted and measured if they exceeded 5.0 cm (2.0 in) in length. Branch length was measured in all species but *Malus*. In *Malus* elongating buds were divided into two categories; those greater than 5.0 cm (2.0 in) but less than 15.0 cm (5.9 in) long and those greater than 15.0 cm (5.9 in). The number of buds less than 5 cm (2.0 in) long was counted, but not measured. Percent branching was expressed as a percentage of extant buds elongating >5 cm (2 in). Distance on central leader over which lateral branching occurred was measured, above and below the height of plant at time of treatment. For those taxa that formed basal branches (branches originating within 50 cm [19 in] of the whip's base), the distance from the soil surface to point of attachment on the trunk of the most apical basal branch was measured.

Data was subject to ANOVA using a fixed effects model with six (five for *Amelanchier*) single tree replications. Means were separated using Student-Newman-Keuls test of significance at $\alpha = 0.05$ level of significance.

Results and Discussion

Cercis chinensis 'Avondale'. On August 4 *Cercis* whips averaged 54 cm (1.8 ft) in height, 5.6 mm (0.2 in) in caliper and had 23 nodes. The central leaders of all whips were in active elongation when sprayed. Cyclanilide reduced central leader elongation rate for three to four weeks after application relative to the control whips (data not presented). This was true for all the taxa. The number of nodes produced after spraying was not affected by CYC treatment (Table 1). The increase in trunk caliper was less at CYC concentrations of 112 and 223 ppm than for whips treated with 0 ppm CYC (Table 1). However, there was no difference in trunk caliper

Table 1. Increase in growth and branching in *Cercis chinensis* 'Avondale' following foliar sprays with Cyclanilide.

CYC ppm	Increase in growth (Aug.4 to Sept. 26) Height (cm)	Caliper (mm)	No. nodes	Percentage of elongated extant buds < 5 cm	> 5 cm	Total branch length (cm)	Height:caliper ratio
Control	50[y]a	3.4ab	17a	0a	0a	0a	11.4a
0[z]	47a	4.3b	16a	0a	0a	0a	10.6a
56	41a	3.3ab	15a	0a	12ab	21ab	10.3a
112	38a	2.8a	14a	0a	18b	36b	11.6a
223	44a	3.0a	15a	0a	12ab	26ab	11.6a

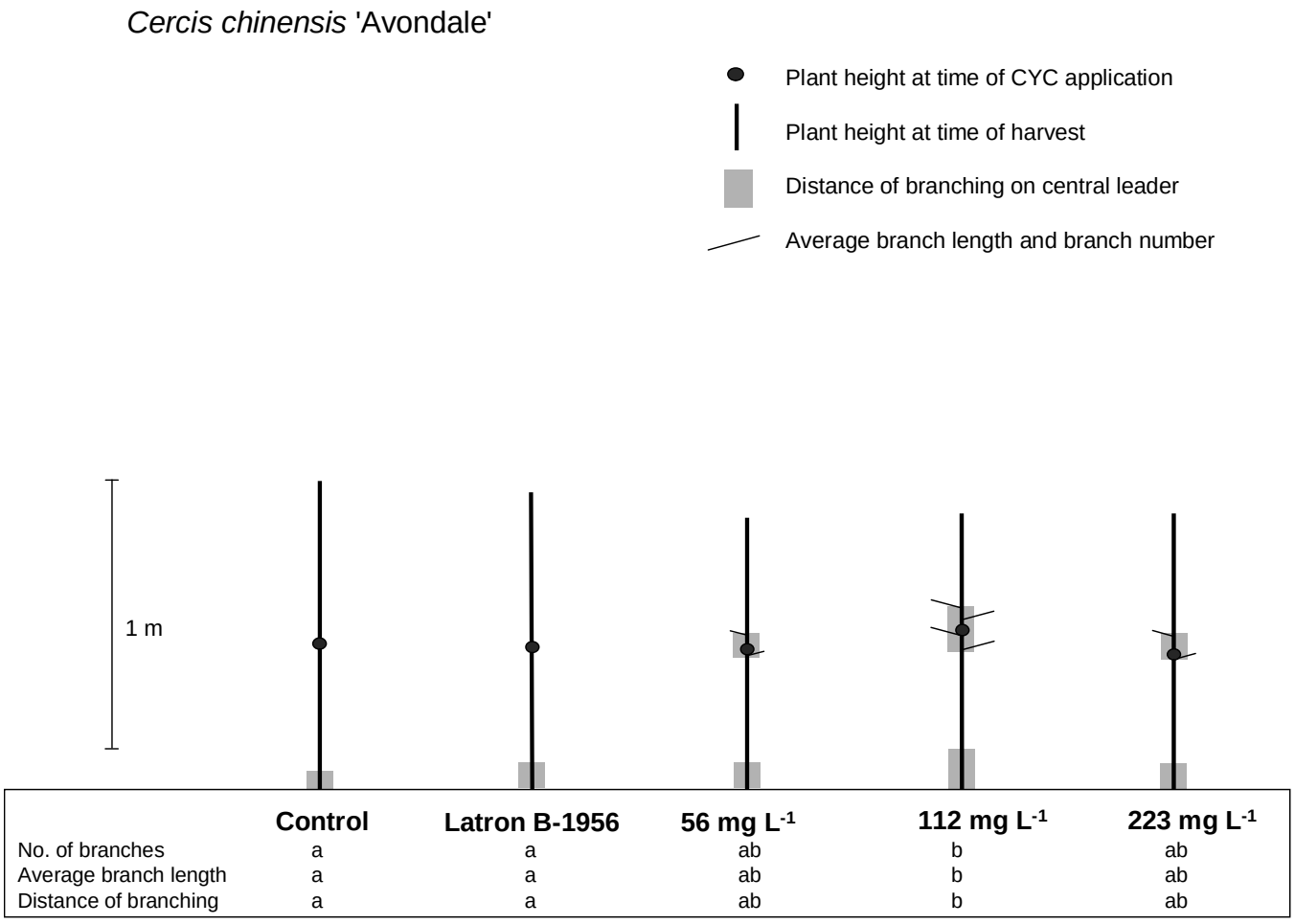
[z]Latron B-1956 was mixed with Cyclanilide treatments at 0.06% (v/v).

[y]Each value is the mean of six single plant replications. Means within a column followed by different letters are significantly different from each other at $\alpha = 0.05$ level of significance using Student-Newman-Keuls test.

increase between whips treated with 0 to 223 ppm and untreated control whips. Height:caliper ratios were not affected by any treatment (Table 1).

For all taxa, branching occurred in two regions on the central leader, either within 50 cm of the whip's base or within 25 cm (10 in) above or below the height of the whip at the time of treatment. No branching occurred between these two regions. Thus, the basal branches (those branches in the lower region) could be clearly distinguished from the branches in the more apical region (Figs. 1 to 4).

Only those whips treated with 112 ppm CYC produced more branches than the 0 ppm CYC treated or control whips (Table 1); most branches were produced from elongation of extant buds (Fig. 1) others were produced from *de novo* buds,



	Control	Latron B-1956	56 mg L^{-1}	112 mg L^{-1}	223 mg L^{-1}
No. of branches	a	a	ab	b	ab
Average branch length	a	a	ab	b	ab
Distance of branching	a	a	ab	b	ab

Fig. 1. Schematic diagram (drawn to scale) of *Cercis chinensis*' Avondale' whips on September 26 following foliar application of Cyclanilide at concentrations of 56, 123 or 223 ppm + 0.06% Latron B-1956 (v/v) on August 7. Control treatments included unsprayed whips or whips sprayed with water to which 0.06% Latron B-1956 (v/v) was added. Each whip is drawn to scale and represents the average of six single whip replications. The lower shaded area represents the distance over which basal buds elongated into shoots >5 cm in length. Branches originating in the upper shaded portions are from either extant (if originating below the height of the whip at the time of treatment) or from *de novo* buds (if originating above the height of the whip at treatment). Different letters within a row indicate treatments significantly different from each other at the $\alpha = 0.05$ level of significance using the Student-Newman-Keuls test.

Table 2. Increase in growth and branching in *Malus* x 'Prairie Fire' following foliar sprays with Cyclanilide.

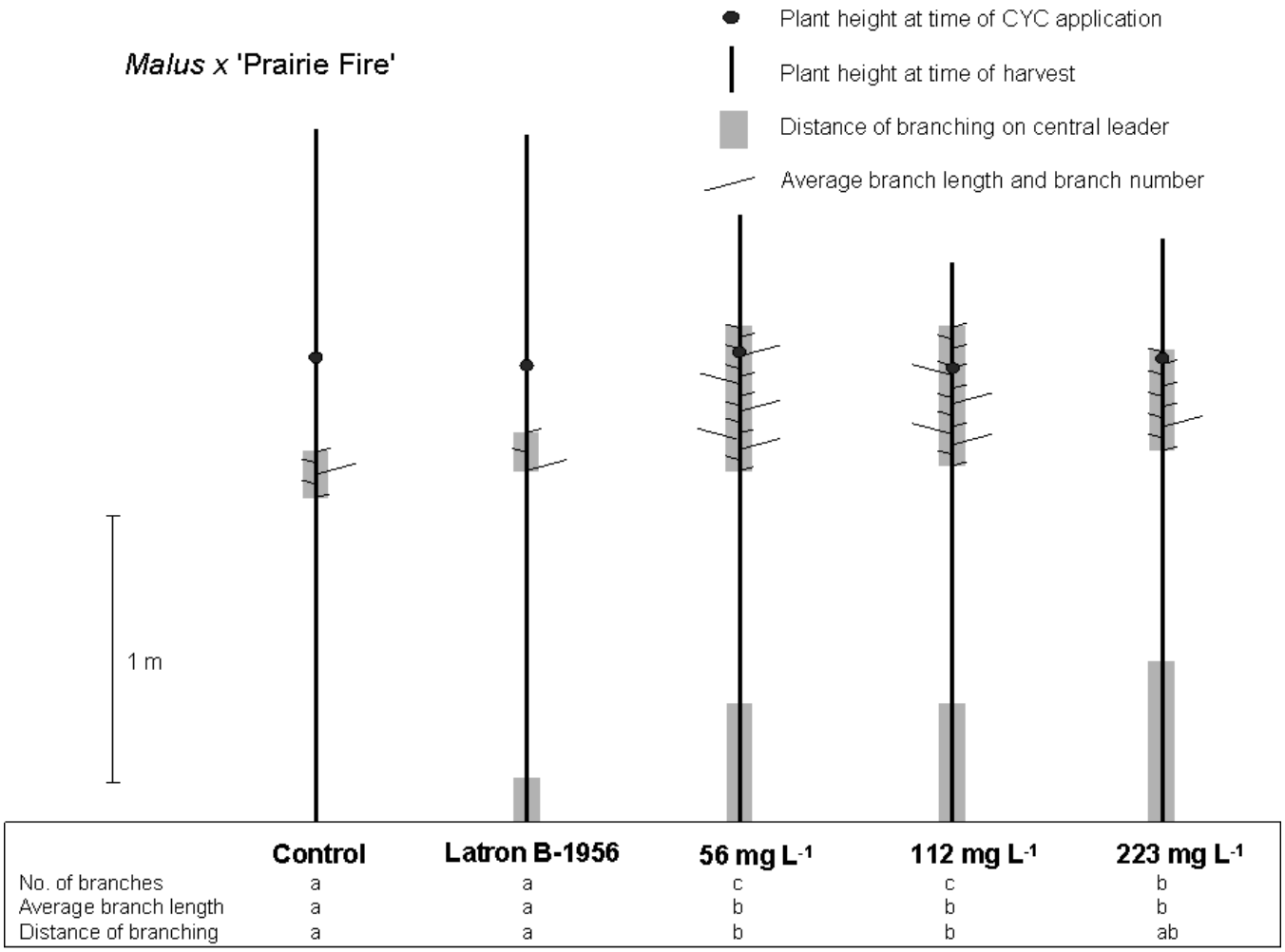
CYC ppm	Increase in growth (Aug.4 to Sept. 26) Height (cm)	Caliper (mm)	No. nodes	Percentage of elongated extant buds < 5 cm	> 5 cm	Total branch length (cm)	Height:caliper ratio
Control	86[y]b	3.8ab	30a	9a	7ab	31a	20.0a
0[z]	82b	4.3b	32a	9a	4a	19a	18.8a
56	51a	2.5a	29a	51b	22c	131b	20.0a
112	40a	2.4a	33a	67b	22c	114b	19.8a
223	45a	3.5ab	24a	62b	14b	56a	18.8a

[z]Latron B-1956 was mixed with Cyclanilide treatments at 0.06% (v/v).

[y]Each value is the mean of six single plant replications. Means within a column followed by different letters are significantly different from each other at $\alpha = 0.05$ level of significance using Student-Newman-Keuls test.

formed on the terminal shoot after CYC application. Branches elongated over a distance of 13 cm (5.1 in) on the central leader, from 5 cm (2.0 in) below to 8 cm (3.1 in) above the whip height at time of CYC treatment (Fig. 1). Cyclanilide® did not affect the number of basal branches formed (data not shown), but sprays of 112 ppm increased the distance on the trunk over which they developed, relative to the control whps ($P = 0.01$). Whips treated with 112 ppm had the greatest total branch length per whip (Table 1). By September 30, terminal shoot elongation had stopped and terminal buds had formed.

Malus x 'Prairie Fire'. On August 4 *Malus* whips averaged 174 cm (5.7 ft) in height, 8.8 mm (0.34 in) in caliper



	Control	Latron B-1956	56 mg L^{-1}	112 mg L^{-1}	223 mg L^{-1}
No. of branches	a	a	c	c	b
Average branch length	a	a	b	b	b
Distance of branching	a	a	b	b	ab

Fig. 2. Schematic diagram (drawn to scale) of *Malus* x 'Prairie Fire' whips on September 26 following foliar application of Cyclanilide at concentrations of 56, 123 or 223 ppm + 0.06% Latron B-1956 (v/v) on August 7. Control treatments included unsprayed whips or whips sprayed with water to which 0.06% Latron B-1956 (v/v) was added. Each whip is drawn to scale and represents the average of six single whip replications. The lower shaded area represents the distance over which basal buds elongated into shoots >5 cm in length. Branches originating in the upper shaded portions are from either extant (if originating below the height of the whip at the time of treatment) or from *de novo* buds (if originating above the height of the whip at treatment). Different letters within a row indicate treatments significantly different from each other at the $\alpha = 0.05$ level of significance using the Student-Newman-Keuls test.

and had 69 nodes. In contrast, the increase in terminal shoot length after CYC treatment was 46 to 59% of the control whip increase (Table 2). There was no significant difference in caliper between treated and untreated whips, but those treated with Latron B-1956 had larger caliper than those treated with 56 and 112 ppm CYC (Table 2). Cyclanilide® application had no effect on the number of nodes developed after spraying (Table 2). Whips treated with 56 and 112 ppm CYC had the greatest number (15) of branches >5 cm (2.0 in) in length. On average, twenty-two percent of extant buds elongated into branches. In contrast control whips averaged five branches greater than 5 cm (Fig. 2). Only CYC spray of 56 ppm produced significantly more branches (five) greater than 15 cm (5.9 in) long. For comparison, control whips developed only one branch greater than 15 cm. Cyclanilide® sprays did not affect the height:caliper ratio (Table 2). Cyclanilide® treatment did not affect the distance over which extant buds elongated, but it did increase the distance that *de novo* buds elongated into shoots (data not shown). While control whips branched over 17 cm (6.7 in) of the central leader, whips treated with CYC at 56 or 112 ppm branched over 50 cm (1.6 ft) in length. Cyclanilide® treated whips (56 to 223 ppm) developed basal branches developed over a greater distance than control whips. By September 30, terminal shoot elongation had stopped and terminal buds had formed.

Amelanchier xgrandiflora 'Autumn Blaze' On August 4 *Amelanchier* whips averaged 99 cm (3.2 ft) in height, 14.7 mm (0.6 in) in caliper and had 38 nodes. Cyclanilide sprays at all concentrations significantly reduced terminal shoot elongation (Table 3). While the terminals of whips in both control groups elongated an average of 62 cm (24.4 in), the whips treated with 223 ppm CYC elongated only half that while those treated with 56 and 112 ppm CYC concentrations elongated only 6 or 7 cm (2.4 or 2.8 in, Fig. 3). Spraying *Amelanchier* whips with CYC significantly reduced caliper and number of nodes (Table 3). Cyclanilide treated whips appeared stunted as a result of reduced number of nodes and internode length. Although CYC treated whips had elongated buds, none elongated more than 5 cm (2.0 in; Fig. 3). Since both height and caliper were significantly reduced by CYC treatment, no significant differences were found in height:caliper ratio. By September 30, terminal shoot elongation had stopped and terminal buds had formed.

Tilia cordata 'Greenspire'. On August 4 *Tilia* whips averaged 97 cm (3.1 ft) in height, 8.0 mm (0.3 in) in caliper and had 22 nodes. Latron B-1956 application increased whip height relative to whips treated with 56 or 112 ppm CYC (Table 4) but was similar to control whips. Application of 112 ppm CYC significantly reduced caliper increase relative to untreated control whips. The number of nodes developed after CYC application was reduced in treated whips at the lower concentrations, relative to the Latron B-1956 treated whips. No difference in number of nodes was observed between the untreated control and the CYC treated whips. The number of branches was increased by CYC, regardless of the concentration relative to both the untreated and the Latron B-1956 treated whips (Fig. 4). Cyclanilide sprays at 112 ppm caused the greatest percentage of extant buds to elongate, 36%. In untreated whips, only 4% of extant buds elongated (Table 4).

The length on the central leader over which buds elongated was significantly greater in those whips treated with either 56 or 112 ppm CYC than control whips (Fig. 4). Concentrations of 56 and 112 ppm CYC increased the total branch length on *Tilia* by 300% compared to the untreated control whips (Table 4). However, CYC sprays of 223 ppm reduced the average branch length by up to 84% compared to sprays of 56 or 112 ppm (Fig. 4). Cyclanilide sprays reduced the number of branches developing at the base of whips ($P = 0.027$) and the distance over which branches formed, compared to untreated control whips ($P = 0.028$; Fig. 2). By September 30, terminal shoot elongation had stopped and terminal buds had formed.

Many deciduous shade trees especially whips, exhibit strong apical dominance during their early years and do not branch readily. Increased branching in whips would increase their value and marketability and reduce production time. Cyclanilide has successfully been used to induce lateral branching in apple and sweet cherry trees under both, nursery and orchard conditions (3, 4, 5) but has not yet been studied for use on shade and ornamental whip production in containers.

This study used taxa with a range of apical dominance strength. Taxa were ranked (in order of decurrent to excurrent growth habit) as: *Amelanchier – Malus* > *Tilia* > *Cercis*.

Most species responded to foliar CYC applications with increased lateral branching. The best response was obtained with sprays of 112 ppm; significantly more branches developed than at 56 ppm or in untreated plants. Applications of 223 ppm did not significantly increase the number of lateral branches in any taxa compared to lower CYC concentrations, and in *Malus*, 223 ppm significantly reduced branch number.

Although CYC increased the number of buds that broke in *Amelanchier*, none of these buds elongated more than 5 cm (2.0 in). According to Cline's (2) terminology, these laterals reached stage 3 (release of apical dominance and initiation of bud elongation) but were not able to proceed into stage 4 (branch development

For the four taxa studied branches induced by CYC application occurred within 24 cm (9.4 in) below and 6 cm (2.4 in) above the whip height at time of application. Thus, it is possible to control the origin of branching by applying CYC when a whip reaches the height where the first branches are desired. For example, if branching at 2 m (6.6 ft) height is a production goal, then whips can be sprayed when the central leader is approximately 2 m in height and in active shoot elongation. Therefore, a producer can begin to engineer a whip with respect to branch origin. However, the origin of the lateral branch is species specific. The species in this study developed branches from both extant and *de novo* buds at approximately equal rates. In studies by Elfving and Visser (4) on sweet cherry and apple trees, the lowest induced feather branches developed from *de novo* buds. Cyclanilide sprays did not significantly reduce the number of nodes developed after CYC application (except in *Amelanchier*). Therefore, CYC reduced internode length, but did not affect rate of leaf node initiation.

Asexual propagated *Tilia* usually express a form of topophysis. Branches and leaves are displayed diatropically (at right angles) to gravity (personal observation). *Tilia* sprayed with CYC showed not only increased branching, but expressed orthotropic branching. This 'improved circumfer-

Table 3. Increase in growth and branching in *Amelanchier* x*grandiflora* 'Autumn Blaze' following foliar sprays with Cyclanilide.

CYC ppm	Increase in growth (Aug. 4 to Sept. 26)			Percentage of elongated extant buds		Total branch length (cm)	Height:caliper ratio
	Height (cm)	Caliper (mm)	No. nodes	< 5 cm	> 5 cm		
Control	61[y]b	4.4b	22b	0a	0a	N/A	14.2a
0[z]	65b	4.3b	23b	0a	0a		14.4a
56	6a	1.6a	7a	7b	0a		13.2a
112	5a	1.1a	6a	4ab	0a		13.0a
223	29a	2.5a	10ab	1a	0a		14.0a

[z]Latron B-1956 was mixed with Cyclanilide treatments at 0.06% (v/v).

[y]Each value is the mean of five single plant replications. Means within a column followed by different letters are significantly different from each other at ⟨ = 0.05 level of significance using Student-Newman-Keuls test.

ential distribution of lateral shoots' is also described by Elfving and Visser (5) following CYC application to sweet cherry trees.

In *Malus*, CYC increased the distance over which basal branching occurred. Thus, CYC treated whips would require additional pruning to raise the crown. On the other hand, those short basal branches will likely increase trunk caliper (8, 9) by increasing the photosynthetic surface of the whip as on cultivars and seedlings of *Quercus virginiana* Mill.

Cyclanilide sprays, especially in higher concentrations resulted in significant reductions in height and caliper in some species. The reduction in height following CYC sprays may appear to be a negative result, but whips exceeding 3 m (9.8 ft) in height will typically be top pruned to 2 m (6.6 ft) by

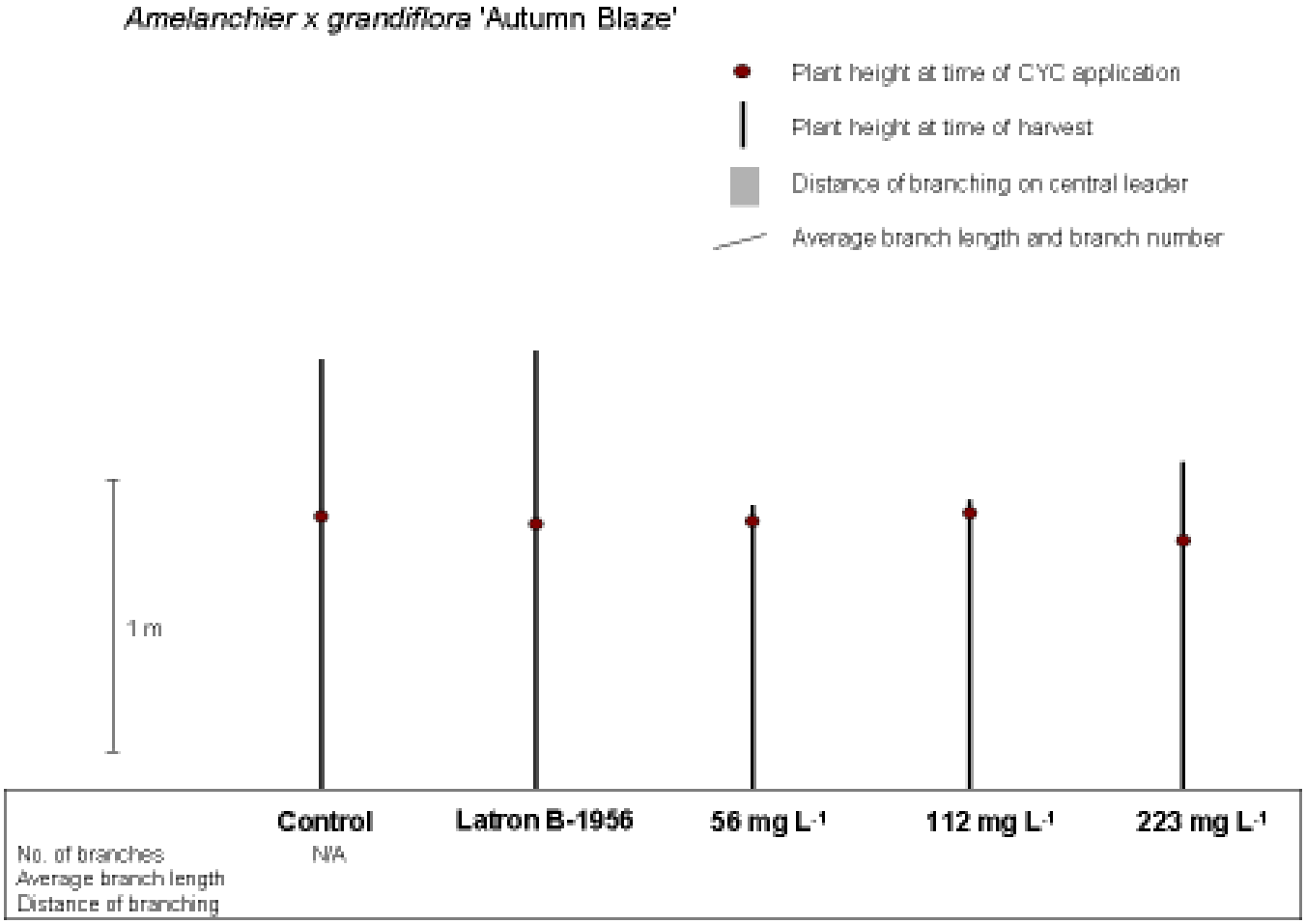


Fig. 3. Schematic diagram (drawn to scale) of *Amelanchier* x *grandiflorum* 'Autumn Blaze' whips on September 26 following foliar application of Cyclanilide at concentrations of 56, 123 or 223 ppm + 0.06% Latron B-1956 (by vol.) on August 7. Control treatments included unsprayed whips or whips sprayed with water to which 0.06% Latron B-1956 (v/v) was added. Each whip is drawn to scale and represents the average of six single whip replications. The lower shaded area represents the distance over which basal buds elongated into shoots >5 cm in length. Branches originating in the upper shaded portions are from either extant (if originating below the height of the whip at the time of treatment) or from *de novo* buds (if originating above the height of the whip at treatment). Different letters within a row indicate treatments significantly different from each other at the α = 0.05 level of significance using the Student-Newman-Keuls test.

Table 4. Increase in growth and branching in *Tilia cordata* 'Greenspire' following foliar sprays with Cyclanilide.

CYC ppm	Increase in growth (Aug.4 to Sept. 26) Height (cm)	Caliper (mm)	No. nodes	Percentage of elongated extant buds < 5 cm	> 5 cm	Total branch length (cm)	Height:caliper ratio
Control	99[y]ab	6.1b	18ab	0a	4a	62ab	13.7a
0[z]	117b	6.3b	24b	0a	1a	6a	15.0a
56	60a	4.6ab	15a	0a	35b	248c	12.7a
112	53a	4.1a	15a	0a	36b	262c	12.7a
223	79ab	4.5ab	20ab	0a	24b	134b	13.7a

[z]Latron B-1956 was mixed with Cyclanilide treatments at 0.06% (v/v).

[y]Each value is the mean of six single plant replications. Means within a column followed by different letters are significantly different from each other at $\alpha = 0.05$ level of significance using Student-Newman-Keuls test.

finish stock producers or by whip producers when producing two-year branched whips. Pruning is done to improve shoot:root ratio and to 'set' the height of lateral branches. A decrease in caliper on the other hand is not desirable, since caliper is an important measure of whip quality (1). In container grown whips, where height growth can be excessive (17), adequate caliper size is important to ensure that the whip can support itself. This becomes even more important when lateral branches are developed since the weight of the crown requires additional trunk strength. One measure of whip quality is the height:caliper ratio. Whips with a smaller height:caliper ratio, assuming they meet minimum height requirements, would be higher quality than a whip with a large height:caliper ratio. Cyclanilide sprays did not affect

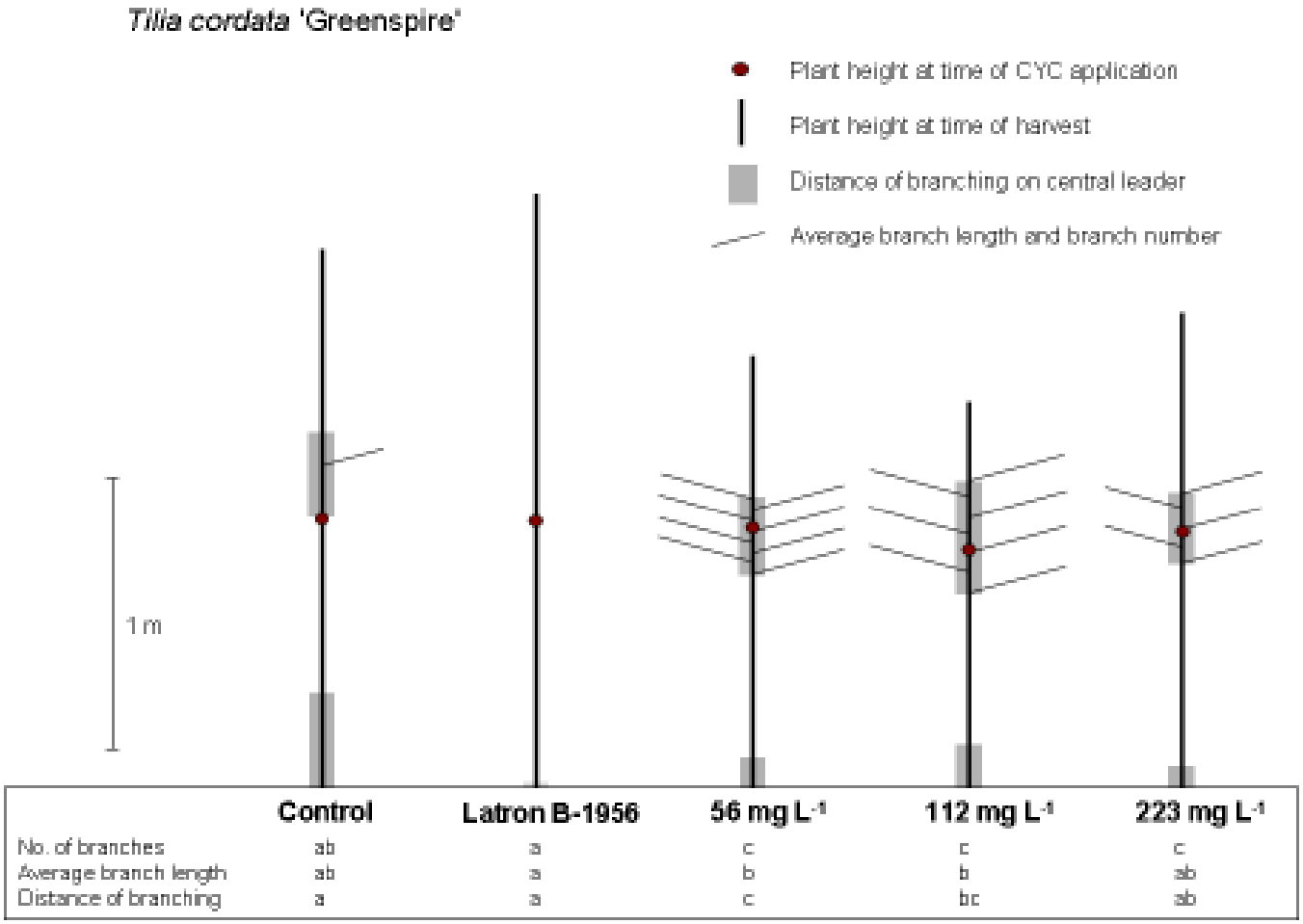


Fig. 4. Schematic diagram (drawn to scale) of *Tilia cordata* 'Greenspire' whips on September 26 following foliar application of Cyclanilide at concentrations of 56, 123 or 223 ppm + 0.06% Latron B-1956 (v/v) on August 7. Control treatments included unsprayed whips or whips sprayed with water to which 0.06% Latron B-1956 (v/v) was added. Each whip is drawn to scale and represents the average of six single whip replications. The lower shaded area represents the distance over which basal buds elongated into shoots >5 cm in length. Branches originating in the upper shaded portions are from either extant (if originating below the height of the whip at the time of treatment) or from *de novo* buds (if originating above the height of the whip at treatment). Different letters within a row indicate treatments significantly different from each other at the $\alpha = 0.05$ level of significance using the Student-Newman-Keuls test.

height:caliper ratios in any of the tested taxa. However, in a similar experiment conducted in 2004, CYC sprays in concentrations between 50 and 200 ppm significantly reduced the height:caliper ratio of Malus 'Prairie Fire'.

Cyclanilide applications of 223 ppm on *Tilia* caused phytotoxicity. The symptoms included marginal leaf necrosis, smaller leaf size and curled leaves. Only growth developing within two to three weeks after CYC application was affected; growth developing later on showed no signs of phytotoxicity. Application of CYC caused *Amelanchier* and *Tilia* to develop reddish foliage and wrinkled leaves on the newest growth of the central leader and its leaves. *Amelanchier*, *Cercis*, *Malus* and *Tilia* showed signs of epinasty and inhibited shoot extension resulting in short internode length. Both are signs of high auxin concentrations and might be caused by an inhibition of polar auxin movement (10, 16)

We suggest that a quick method for predicting those taxa that will respond to CYC sprays by increased branching is the expression these mild phytotoxic symptoms. The taxa in our study that displayed these symptoms after CYC application, all showed improved lateral branching. However, all the symptoms need not to be displayed, as some taxa that did not show all of the side-effects still produced lateral branches after CYC application.

Cyclanilide applications of 112 ppm are best for most species; it induces branching without causing severe caliper decreases or phytotoxic responses. However, the response to CYC is species specific and its effect on whip growth and branching needs to be determined on a case by case basis, before commercial adoption.

Since CYC treated whips are shorter and more highly branched, pruning to induce branching is unnecessary, resulting in labor savings and result in branched whips in the first growing season One advantage of CYC application is that it does not destroy the terminal bud. In contrast pruning results in the loss of the central leader, resulting in an undesirable tree form, unless a central leader is re-established (12, 18).

As described above, the reduction in height caused by CYC applications is desirable, since container grown whips tend to be too tall (17). But the height reduction, combined with increased lateral branching, results in a more desirable crown form. Since the number of nodes developed after CYC application is usually not affected, a short whip with the same number of nodes and more lateral branches than a taller, untreated whip, will appear denser than the tall (2).

Literature Cited

1. American Nursery and Landscape Association. 2004. American Standard For Nursery Stock, ANSI Z-60.1-2004, http://www.anla.org.

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

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

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

6. Femrite Nursery Company, Aurora, OR, 2006, http://www.femrite.com.

7. Flemmer, W. III. 1981. How and when to prune nursery stock. Amer. Nurseryman 153:14, 126–132.

8. Gilman, E.F. 1997. Trees for Urban and Suburban Landscapes. An Illustrated Guide to Pruning. Delmar Publishers, Albany, NY.

9. Gilman, E.F., P.J. Anderson, and C. Harchich. 2006. Pruning lower branches of live oak (*Quercus virginiana* Mill.) cultivars and seedlings during nursery production: Balancing growth and efficiency. J. Environ. Sci. 24:201–206.

10. Hansen, H. and K. Grossmann. 2000. Auxin-induced ethylene triggers abscisic acid biosynthesis and growth Inhibition. Plant Physiol. 124:1437–1448.

11. Jacyna, T., C.J. Starbuck, and M.R. Ellersiek. 1994. Increasing branching of landscape pear trees with Promalin and dikegulac-sodium. J. Environ. Sci. 12:90–92.

12. Larsen, R.B. 1978. Stimulation of lateral branching of azaleas with dikegulac-sodium (Atrinal). J. Hort. Sci. 53:57–62.

13. Loreti, F. and P.L. Pisani. 1990. Structural manipulation for improved performance in woody plants. HortScience 25:64–70.

14. Lyon, R. 2006. Sunleaf Nursery. Madison, OH, Personal communication

15. Pedersen, M.K. 1998. The mechanism of action of cyclanilide, an ethephon synergist. The North Carolina State University, Dissertation.

16. Sengbusch,P. 2006. www.botanyonline.de.

17. Stoven, A.A., H.M. Mather, and D.K. Struve. 2006. Fertilizer application method affects growth, nutrient, and water use efficiency of container grown shade tree whips. HortScience 41:1206–1212.

18. Wright, D.C and J.T. Moran. 1988. Adverse effects of Atrinal on plane tree, red maple and Norway maple. J. Arboriculture 14:125–128.