Growth Response of Crapemyrtle to Production Light Level and Supplemental Fertilizer[1]

K.M. Brooks[2], G.J. Keever[3], J.L. Sibley[4], and J.E. Altland[5]
Department of Horticulture
Auburn University, AL 36849

Abstract

The effects of production light level on growth of crapemyrtle were evaluated as a means of accelerating the development of tree-form crapemyrtles (*Lagerstroemia* spp.). By the end of the first growing season, plant height and shoot length of 'Fantasy' and 'Tuscarora' were greater when grown under 50 or 80% shade than when grown in full sun. By the end of the second growing season, height and shoot length of all three cultivars grown under one or both shade levels were greater than those of plants grown in full sun. In a second experiment, 'Carolina Beauty' and 'Tuscarora', but not Dynamite™, were taller at the end of the first growing season when grown under 50 or 80% shade than when grown in full sun. Flowering of all cultivars grown under shade was suppressed or delayed. Caliper of Dynamite™ and 'Tuscarora' at the end of the first growing season was greatest when grown in full sun, while production light level had no effect on caliper of 'Carolina Beauty'. At the end of the second season, during which all plants were grown in full sun, there were no height, caliper, or flowering differences of any cultivar due to previous production light level, except for less caliper growth of 'Tuscarora' previously under 80% shade compared to plants grown in full sun.

Index words: container production, flowering trees, *Lagerstroemia*.

Species used in this study: 'Tuscarora' (*Lagerstroemia indica* L. ×*fauriei* Koehne), 'Fantasy' (*Lagerstroemia fauriei*), 'Whit II' (Dynamite™) and 'Carolina Beauty' (*Lagerstroemia indica* L.).

Significance to the Nursery Industry

Most cultivars of crapemyrtle are vigorous growers under nursery conditions; however, some cultivars begin flowering by early summer, resulting in suppressed vegetative growth, particularly height growth, a problem often compounded by heavy fruit set later in the growing season. Pruning of inflorescences is labor-intensive and results in rapid re-bloom. For production of standard (single trunk) or multi-trunk (usually three) tree-forms of crapemyrtle with 112 to 183 cm (4 to 6 ft) of clear trunk, pruning exacerbates the problem by stimulating new shoot formation, often from the main trunk. Our research showed that the use of lower light levels in the production of tree-form crapemyrtles can accelerate height growth and delay flowering, but caliper may be reduced. Plants developed sufficient clear trunk height the first season so that canopy development (not a part of this study), rather than additional height growth, would be the focus during subsequent years of production. In addition, any caliper reduction from previous production in shade may be regained if plants are grown in full sun the second season.

Introduction

Crapemyrtles (*Lagerstroemia* spp.), grown in the southern and southwestern United States and along the West Coast as shrubs or small trees, are valuable landscape species recognized for their exceptional seasonal ornamental characteristics. Lengthy summer flowering and a diversity of flower colors, plant sizes, and growth habits are appreciated by horticulturalists and gardeners (3). Breeding programs over the last 30 years have produced superior forms of crapemyrtle with a wide range of plant sizes and habits, improved flowering, new flower colors, ornamental bark, ornamental foliage, disease resistance and increased vigor (9).

Most cultivars of crapemyrtle are vigorous growers under nursery conditions; however, some cultivars begin flowering as early as May and continue into the fall (2, 9). Early flowering can suppress vegetative growth, particularly height growth. Height suppression is often compounded by heavy fruit set later in the growing season. In addition, panicles are often large and heavy, resulting in split trunks during irrigation or rainfall and frequent blow-over of container-grown trees. Manual flower removal may alleviate some of these problems, but is labor-intensive and costly, and plants quickly initiate new inflorescences on short shoots that suppress vegetative growth (personal observations). For production of standard (single trunk) or multi-trunk (usually three) tree-forms of crapemyrtle with 112 to 183 cm (4 to 6 ft) of clear trunk, pruning exacerbates the problem by stimulating new shoot formation, often from the main trunk.

Three major mechanisms that can control the development of tree-form are: 1) apical dominance, which can affect both the pattern and orientation of axes development; 2) allocation mechanisms that maintain feedbacks between leaf and wood production for both transport capacity and mechanical support; and 3) shading that reduces light intensity (19). Apical dominance, the control exerted by the apical portions of the shoot over the outgrowth of lateral buds (5), is strengthened under lower light conditions (1, 10). Leaf shading beneath a plant canopy enriches the far-red component of transmitted light and causes a reduction of the fluence rate (irradiance) and light quality (6). Shading can reduce photosynthesis which may eventually reduce leaf production and growth. However, plants in shade tend to grow upward to reach the canopy surface where they will be able to collect more light (19). Far-red light inhibits the initiation of bud outgrowth and also enhances subsequent bud elongation after it has been initiated (13, 17). This upward growth can be useful in obtaining tree-form crapemyrtles.

[1]Received for publication April 6, 2006; in revised form August 7, 2006.

[2]Graduate Student.
[3]Professor; keevegj@auburn.edu.
[4]Alumni Associate Professor.
[5]Assistant Professor of Horticulture, Oregon State University, North Willamette Research & Extension Center, Aurora, OR.

Vegetative growth and flowering are regulated by several factors including photoperiod, accumulated light intensity, and temperature (14). High temperatures favored rapid floral bud initiation and development in dwarf crapemyrtles (8), while heavy shade suppressed flowering and axillary shoot growth (18, 19). While detrimental from a landscape perspective, shade-induced flower suppression may create growing opportunities for wholesale nurseries. In addition, high levels of fertilizers, especially nitrogen (N), stimulate vegetative growth and may reduce flowering. Growth control often depends on the interaction between environmental and genetic factors (11) and manipulation requires an understanding of the species. The value of woody landscape plants is generally dictated by size (i.e., height and spread), and nursery growers favor practices that maximize growth (4). Therefore, the objective of this study was to evaluate the effect of production light level and supplemental topdressed fertilizer on vegetative growth during nursery production of tree-form crapemyrtle. Our overall goal was to accelerate height growth so that canopy or head development could be begun sooner.

Materials and Methods

Experiment 1. Research was conducted outdoors under nursery conditions at Auburn University's Paterson Horticultural Complex in Auburn, AL (32º 36' N x 85º 29' W; USDA Cold Hardiness Zone 8a). Liners of *Lagerstroemia indica* 'Carolina Beauty' and *Lagerstroemia fauriei* 'Fantasy', two cultivars with mature heights of 6 m (20 ft) or more, were repotted from 10.2 cm (4 in) pots into11.4 liter (#3) pots on October 1, 2002. The 8:1 (by vol) pinebark:sand substrate was amended per m^3 (yd^3) with 8.3 kg (14 lb) of 17N–2.2P–9.1K (Polyon 17–5–11, Pursell Industries, Sylacauga, AL), 0.9 kg (1.5 lb) Micromax (The Scotts Company, Marysville, OH) and 3 kg (5 lb) dolomitic limestone. Dormant *Lagerstroemia indica ×fauriei* 'Tuscarora' liners [mature height of 6 m (20 ft) or more] were repotted into 3.8 liter (#1) from 10.2 cm (4 in) pots using the same substrate on March 12, 2003. 'Carolina Beauty' and 'Fantasy' were pruned to 59 cm (23 in) in height to improve uniformity, and one-half of the plants of each cultivar were topdressed with 70 g (2.5 oz) of 17N–2.2P–9.1K (Polyon 17–5–11) on July 15, 2003. One-half of 'Tuscarora' [30 cm (12 in) tall] were topdressed with 40 g (1.4 oz) on the same date. One-third of the plants of each cultivar, half of which had received topdressed fertilizer, were spaced 0.6 m (2 ft) apart in full sun, under 50% shade or under 80% shade and watered with overhead impact sprinklers as needed. Shade treatments were obtained by covering a structure [4.3 m H (14 ft) × 31.7 m L (104 ft) × 3.7 m W (12 ft)] with a single or double layer of 50% shade fabric. Light level under two layers of shade fabric were approximately 80% less than in full sun. 'Fantasy' and 'Tuscarora' were replicated with 10 plants and 'Carolina Beauty' was replicated with 7 plants, and the topdressed treatments were randomized within cultivar. Height from the substrate surface to the tallest part of the plant and the length of the three longest shoots, measured from the base of the shoot to the tip and including inflorescences if present, were measured on August 9, September 9, and October 15, 2003. The average length of the three longest shoots was then calculated.

'Carolina Beauty' and 'Fantasy' were repotted into 38 liter (#10) pots and 'Tuscarora' into 11.4 liter (#3) pots containing the previously described substrate on December 12, 2003. Plants were trained into tree-form by removing all shoots except the three previously measured on February 24, 2004. Plants remained under the three light regimes during the second year of the experiment. Plants in 38 liter (#10) pots and 11.4 (#3) pots previously topdressed were topdressed again on June 16, 2004, with 180 g (6.3 oz) and 70 g (2.5 oz), respectively, of 17N–2.2P–9.1K (Polyon 17–5–11). Plant height and length of the three longest shoots were measured on April 20, June 3, August 9, and October 29, 2004.

Experiment 2. On March 16, 2004, 60 dormant plants each of *Lagerstroemia indica* 'Carolina Beauty' and 'Whit II' Dynamite™ [mature height of 3 to 6 m (10–20 ft)] and *Lagerstroemia indica ×fauriei* 'Tuscarora' were repotted from 10.2 cm (4 in) liner pots into either 3.8 liter (#1) ('Carolina Beauty') or 11.4 liter (#3) pots containing the previously described substrate. 'Carolina Beauty' were 12 cm (4.7 in) tall, 'Tuscarora' were 21 cm (8.3 in) tall, and Dynamite™ were 11 cm (4.3 in) tall when repotted. Plants were pruned if necessary to remove any lateral branches and spaced 0.6 m (2 ft) apart in full sun, under 50% shade or under 80% shade and watered with overhead impact sprinklers as needed. One-half of the plants of each cultivar under each light regime were topdressed with 40 g (1.4 oz) [3.8 liter (#1) pots] or 70 g (2.5 oz) [11.4 liter (#3) pots] of 17N–2.2P–9.1K (Polyon 17–5–11) on June 16, 2004. One shoot was selected and all laterals were removed weekly during the growing season. Height was measured from the substrate surface to the tip of the single shoot and caliper was measured 2.5 cm (1 in) from the substrate surface on April 26, June 23, August 26, and October 28, 2004. The presence of flower color was noted at each data collection. Treatments were replicated with 10 single plants and topdressed treatments were randomized within cultivar.

On February 18, 2005, 'Carolina Beauty' was repotted into 11.4 liter (#3) pots containing the previously described substrate. Dynamite™ and 'Tuscarora', which remained in 11.4 liter (#3) pots, were topdressed with 70 g (2.5 oz) of 17N–2.2P–9.1K (Polyon 17–5–11). All plants were grown in full sun in 2005, and the supplemental topdress treatments were discontinued. Height, caliper and the presence of flowering were recorded on April 7, June 3, August 3, and October 3, 2005.

In both experiments, data were subjected to analysis of variance using SAS (15). Since supplemental fertilization was not significant as a main effect and there were no interactions between light regime and supplemental fertilization, light treatments were pooled across fertilizer treatments. Light treatment means were separated using Duncan's Multiple Range Test ($\alpha = 0.05$).

Results and Discussion

Experiment 1. Height of 'Tuscarora' grown under 80% shade was 73 and 124% greater in September and October, respectively, than plants grown in full sun, which were similar in height to plants grown under 50% shade (Table 1). Likewise, shoot length of plants under 80% shade increased from 30% greater than plants in full sun in August to 118 and 126% greater in September and October, respectively. Shoot length of plants under 50% shade and in full sun was similar. Increased height growth under shade was probably due to the enriched far-red light which enhanced shoot elongation (6, 13, 17). Similar to 'Tuscarora', 'Fantasy' grown under

Table 1. **Effect of production light level on growth of three container-grown crapemyrtle cultivars in Auburn, AL; Expt. 1, 2003.**

Light regime	Height (cm)			Shoot length (cm)[z]		
	Aug.	Sept.	Oct.	Aug.	Sept.	Oct.
			'Tuscarora'			
Sun	42.8a[y]	44.2b	44.9b	33.0b	27.2b	29.2b
50% Shade	46.1a	51.1b	59.1b	34.5b	35.1b	37.9b
80% Shade	49.1a	76.3a	100.8a	42.8a	59.4a	66.0a
			'Fantasy'			
Sun	79.4a	121.8a	124.0b	47.9a	72.2b	73.7c
50% Shade	82.0a	120.8a	130.0b	48.6a	83.7a	86.2b
80% Shade	84.7a	138.7a	150.7a	47.9a	91.9a	96.7a
			'Carolina Beauty'			
Sun	78.0a	125.0b	128.9a	32.1a	68.6a	71.2a
50% Shade	83.5a	144.1a	146.1a	34.1a	83.7a	84.9a
80% Shade	80.6a	127.1b	140.4a	28.9a	75.7a	76.7a

[z]Means of the three longest shoots.

[y]Means within columns and cultivar separated by Duncan's Multiple Range Test, $\alpha = 0.05$.

80% shade were 21% taller than plants in full sun in October, while height of plants in full sun and under 50% shade was similar. Shoot length of 'Fantasy' under 50 and 80% shade was similar in September, and greater than that of plants in full sun. By the end of the growing season, shoot length of 'Fantasy' under 80% shade was 12 and 31% greater than that of plants under 50% shade and in full sun, respectively, while shoot length of plants under 50% shade was 17% greater than that of plants in full sun. Height of 'Carolina Beauty' under the three production light levels was similar, except in September when height of plants under 50% shade was 15 and 13% greater than that of plants grown in full sun and under 80% shade, respectively. Light level did not affect shoot length of 'Carolina Beauty' at any time.

In the second year of the experiment, 'Tuscarora' remained taller under shade, except in June when plants under the three light regimes were similar in height. 'Tuscarora' grown under 50% shade was 82 and 28% taller in August than plants in full sun and under 80% shade, respectively (Table 2). By October, plants under 80% shade were similar in height to plants under 50% shade and 64% taller than plants in full sun. Shoot lengths of 'Tuscarora' under the three light regimes were similar in April and August, but by the end of the growing season, shoots of plants under 50% shade were 36% longer than those of plants grown in full sun and similar to those of plants under 80% shade. Similar to the previous October, 'Fantasy' remained tallest in April and June when grown under 80% shade; these plants were similar in height to plants grown under 50% shade in August and October, but 28% taller than plants in full sun by the end of the growing season. Shoots of 'Fantasy' remained longest in April and June when grown under 80% shade. Shoots of these plants were similar in length to those of plants under 50% shade, but 49 and 40% longer than those of plants in full sun in August and October, respectively. Similar to 'Fantasy' in April and June, 'Carolina Beauty' was tallest at each data collection when grown under 80% shade, while plants under 50% shade were similar in height to plants in full sun in April and June but taller in August and October. Shoots of 'Carolina Beauty' were also longest at each data collection when grown under 80% shade, except in June when shoots were similar in length to plants under 50% shade.

Supplemental fertilization did not affect growth of any cultivar (results not shown). We speculate the 12-month topdressed fertilizer used in this experiment released at a rate too slow to cause measurable differences, the released nitrogen volatilized, or both.

Experiment 2. Height of 'Tuscarora' grown under 80% shade was 14% greater than that of plants under 50% shade and similar to that of plants in full sun in April (Table 3). In June, plants in full sun were 22% taller than plants under 80% shade and similar to plants under 50% shade. Higher light intensity and concomitant increased temperature in full

Table 2. **Effect of production light level on growth of three container-grown crapemyrtle cultivars in Auburn, AL; Expt. 1, 2004.**

Light regime	Height (cm)				Shoot length (cm)[z]			
	Apr.	June	Aug.	Oct.	Apr.	June	Aug.	Oct.
				'Tuscarora'				
Sun	43.4c[y]	126.4a	101.3c	114.7b	30.2a	91.4b	95.0a	92.3b
50% Shade	66.1b	153.7a	185.0a	185.6a	44.7a	126.8a	124.9a	125.9a
80% Shade	100.0a	137.6a	144.0b	187.7a	42.7a	86.8b	104.0a	110.2ab
				'Fantasy'				
Sun	134.6b	183.1b	203.1b	205.6b	71.2b	118.7b	133.5b	138.4b
50% Shade	132.4b	179.6b	241.4ab	232.1ab	75.5b	128.9b	189.9a	188.2a
80% Shade	169.4a	211.2a	278.0a	263.0a	109.9a	163.5a	196.0a	192.9a
				'Carolina Beauty'				
Sun	113.0b	173.7b	176.7c	176.3c	60.8b	114.2b	104.1b	103.8c
50% Shade	123.7b	180.3b	208.7b	202.0b	75.2b	137.8ab	127.8b	129.9b
80% Shade	164.7a	201.9a	250.3a	251.4a	105.4a	150.8a	174.4a	172.3a

[z]Means of the three longest shoots.

[y]Means within columns and cultivar separated by Duncan's Multiple Range Test, $\alpha = 0.05$.

Table 3. Effect of production light level on growth of three container-grown crapemyrtle cultivars in Auburn, AL; Expt. 2, 2004.

Light regime	Height (cm)				Caliper (mm)			
	Apr.	June	Aug.	Oct.	Apr.	June	Aug.	Oct.
				'Tuscarora'				
Sun	21.8ab[z]	76.4a	85.2b	85.4b	3.1a	9.3a	13.2a	12.6a
50% Shade	19.4b	70.1ab	103.6ab	106.4ab	3.0ab	6.3b	10.1b	10.0b
80% Shade	22.2a	62.2b	114.3a	116.2a	2.6b	6.1b	9.3b	9.8b
				'Carolina Beauty'				
Sun	12.2a	57.2a	69.8b	68.0b	2.6a	5.7a	7.9a	7.9a
50% Shade	13.1a	56.9a	99.9a	104.3a	2.7a	4.0b	6.7b	7.4a
80% Shade	11.2a	54.9a	97.2a	96.8a	2.6a	4.3b	7.1b	7.1a
				Dynamite™				
Sun	11.8a	52.3a	70.4a	71.1a	2.3ab	6.1a	10.3a	10.3a
50% Shade	12.2a	29.5b	71.2a	67.2ab	2.4a	3.0b	6.9b	6.7b
80% Shade	10.4b	25.2b	58.8b	58.3b	1.9b	2.7b	5.4c	6.1b

[z]Means within columns and cultivar separated by Duncan's Multiple Range Test, α = 0.05.

sun may have stimulated vegetative growth and caused the early season height advantage (16). Plant height under 80% shade was similar to that of plants under 50% shade and 34 and 36% greater than that of plants in full sun in August and October, respectively. Again, the increased height under shade was probably due to enriched far-red light enhancing shoot elongation. In full sun 95% of 'Tuscarora' had flowered or were flowering in August compared to 55% of plants under 50 or 80% shade. Height growth of plants in full sun may have been reduced by the flowering of terminal shoots, which was reported to reduce shoot extension (7, 12). Heights of 'Carolina Beauty' under the three light regimes were similar in April and June and greater under shade thereafter. Plants grown under 80% shade were similar in height to plants under 50% shade and 39 and 42% taller than plants in full sun in August and October, respectively. Similar to 'Tuscarora', 72 and 90% of 'Carolina Beauty' grown in full sun were flowering in August and October, respectively, compared to 0 and 10% under 50% shade and 10 and 0% under 80% shade, which probably suppressed shoot length in full sun. In contrast to 'Tuscarora' and 'Carolina Beauty', Dynamite™ grown in full sun were taller than those under 80% shade at all data collections and similar to plants grown under 50% shade in June, August, and October, although 83 and 95% of plants in full sun were flowering in August and October, respectively, while none flowered in shade. There was no treatment effects due to the addition of supplemental topdressed fertilizer on any cultivar tested (results not shown).

Caliper of 'Tuscarora' in full sun was greater than that of plants under 80% shade in April and greater than that of plants under both shade treatments thereafter. Plants in full sun had 26 and 28% greater caliper in October than plants under 50 and 80% shade, respectively (Table 3). Caliper of 'Carolina Beauty' in full sun was greater in June and August than that

Table 4. Effects of 2004 light level on growth of three container-grown crapemyrtle cultivars grown in full sun in 2005 in Auburn, AL; Expt. 2.

2004 Light regime	Height (cm)				Caliper (mm)			
	Apr.	June	Aug.	Oct.	Apr.	June	Aug.	Oct.
				'Tuscarora'				
Sun	84.0b[z]	124.7a	197.0a	195.3a	12.4a	15.3a	22.1a	24.9a
50% Shade	106.4ab	139.0a	180.1a	186.0a	10.7ab	13.9a	20.7ab	22.8ab
80% Shade	114.7a	140.8a	196.2a	198.2a	9.5b	11.6b	18.4b	21.6b
				'Carolina Beauty'				
Sun	66.3b	101.1a	153.7a	158.0a	7.5a	8.7a	14.9a	17.4a
50% Shade	91.9a	107.3a	147.1a	153.6a	7.1a	7.8a	14.0a	16.9a
80% Shade	97.0a	121.5a	153.4a	154.4a	7.0a	8.3a	13.9a	16.7a
				Dynamite™				
Sun	69.8a	92.7a	125.3a	130.8a	10.5a	11.8a	12.8a	16.4a
50% Shade	65.1a	81.1a	129.0a	127.3a	6.5b	7.9b	11.8a	16.0a
80% Shade	63.7a	81.9a	136.9a	136.6a	6.3b	8.3b	13.0a	16.4a

[z]Means within columns and cultivar separated by Duncan's Multiple Range Test, α = 0.05.

of plants grown under shade treatments. However, calipers were similar by the end of the growing season. The continued growth of plants under shade due to suppressed or delayed flowering may explain why calipers were similar to plants in full sun by the end of the growing season. Caliper of Dynamite™ responded similarly to that of 'Tuscarora', with caliper of plants grown in full sun similar to that of plants under 50% shade in April, then greater thereafter than that of plants under both shade treatments.

In the second year of the experiment when all plants were grown in full sun, 'Tuscarora' previously grown under 80% shade were 37% taller than plants in full sun and similar in height to plants under 50% shade in April, but there were no differences thereafter (Table 4). Similar to 'Tuscarora', height of 'Carolina Beauty' was greater for plants previously grown under shade in April but similar thereafter. Previous production light level had no effect on height of Dynamite™ at any data collection. There were no obvious flowering differences due to previous production light levels in any cultivar tested.

Caliper of 'Tuscarora' in full sun remained greater than that of plants under 80% shade in the second year. However, plants previously grown under 50% shade, which had 21% less caliper at the end of the first season, were similar in caliper to plants in full sun at each data collection during the second year (Table 4). Caliper of 'Carolina Beauty' was similar throughout the growing season regardless of previous production light level. Similar to 'Tuscarora', caliper of Dynamite™ in full sun was greater in April and June than that of plants previously grown under 50 and 80% shade. Calipers of Dynamite™ in August and October were similar regardless of previous production light levels.

Results of this study show height growth of all cultivars, except Dynamite™, was generally greater when grown under shade during the first year. Through the use of lower production light levels it was possible to accelerate height growth of 'Fantasy', 'Tuscarora', and 'Carolina Beauty', while 'Fantasy' and 'Carolina Beauty' grown under 80% shade, exhibited some height advantage over plants grown under 50% shade. By growing Dynamite™ and 'Tuscarora' in full sun the second year it was possible to regain caliper lost due to growth under shade the previous year, while calipers of 'Carolina Beauty', previously under the three light regimes, remained similar in the second season. The height advantage gained by growing plants in shade during the first year was lost during the second year when grown in sun. However, plants developed sufficient clear trunk height the first season so that canopy or head development rather than additional height could be the focus in subsequent production years. The increase in caliper when grown in full sun the second year along with the height advantage gained from growing under lower light levels the first year may benefit tree-form crapemyrtle production.

Literature Cited

1. Anderson, A.S. 1976. Regulation of apical dominance by ethephon, irradiance, and CO_2. Physiol. Plant. 37:303–308.

2. Byers, M.D. 1997. Crapemyrtle, a Grower's Thoughts. Owl Bay Publishers, Auburn, AL.

3. Cabrera, R.I. 2004. Evaluating and promoting the cosmopolitan and multipurpose *Lagerstroemia*. Acta Hort. 630:177–184.

4. Cabrera, R.I. and D.R. Devereaux. 1998. Effects of nitrogen supply on growth and nutrient status of containerized crapemyrtle. J. Environ. Hort. 16:98–104.

5. Cline, M.G. 1991. Apical dominance. Bot. Rev. 57:318–358.

6. Deregibus, V.A., R.A. Sanchez, and J.J. Casal. 1983. Effects of light quality on tiller production in *Lolium* spp. Physiol. Plant. 72:900–902.

7. Fain, G.B., C.H. Gilliam, and G.J. Keever. 2001. Response of *Lagerstroemia* × 'Tuscarora' to Pistill and Atrimmec. J. Environ. Hort. 19:149–152.

8. Guidry, R.K. 1977. Forcing Dwarf Crapemyrtles. M.S. Thesis. Univ. of Arkansas, Fayetteville.

9. Knox, G.W. 2003. Crapemyrtle in Florida. Fla. Coop. Ext. Serv. Publ. EHN-52.

10. Kohyama, T. 1980. Growth pattern of *Abies mariesii* under conditions of open growth and suppression. Bot. Mag. Tokyo 93:13–24.

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

12. Morrison, T.A., G.J. Keever, and C.H. Gilliam. 2003. Response of *Lagerstroemia* × 'Tuscarora' to multiple applications of Pistill. J. Environ. Hort. 21:169–172.

13. Morgan, D.C. and H. Smith. 1986. Non-photosynthetic responses to light quality. p. 109–134. *In*: O.L. Lange, P.S. Nobel, C.B. Osmond, and H. Ziegler (eds.), Encyclopedia of Plant Physiology. New series Vol. 12A Physiological Plant Ecology I. Springer-Verlag, New York.

14. Rawson, J.M. and R.L. Harkess. 1997. Growth and flowering of *Lagerstroemia* in response to photoperiod and fertilization rates. Proc. South. Nurs. Assoc. Res. Conf. 42:39–43.

15. SAS Institute. 2003. SAS/STAT User's Guide: Release 9.1 ed. SAS Inst., Cary, NC.

16. Stimart, D.P. 1986. *Lagerstroemia*. p. 187–190. *In*: A.H. Halevy (ed.), CRC Handbook of Flowering. CRC Press, Boca Raton, FL. Vol. V.

17. Tucker, D.J. and T.A. Mansfield. 1972. Effects of light quality on apical dominance in *Xanthium strumarium* and the associated changes in endogenous levels of abscisic acid and cytokinins. Planta 102:140–151.

18. Wade, G.L. and J.W. Woodward. 2001. Crape Myrtle Culture. Georgia Coop. Ext. Serv. Leaflet 331.

19. Wilson, B.F. 1990. The development of tree form. HortScience 25:52–54.