ACCELERATED PRODUCTION OF TREE-FORM CRAPEMYRTLE

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ACCELERATED PRODUCTION OF TREE-FORM CRAPEMYRTLE

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ACCELERATED PRODUCTION OF TREE-FORM CRAPEMYRTLE

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Kevin M. Brooks, son of Jerry and Anita Brooks, was born January 2, 1980 in Birmingham, Alabama. He graduated from Hewitt-Trussville High School, Trussville, AL, in May 1998. He entered Jefferson State College in August 1998 and transferred to Auburn University in August 1999 where he graduated with a Bachelor of Science degree in Agronomy and Soils in December 2003. Kevin entered graduate school in the Department of Horticulture at Auburn University in January 2004 and pursued a Master of Science degree under the guidance and direction of Dr. Gary J. Keever. While at Auburn, he was employed as a graduate research fellow. He received his Master of Science degree on May 11, 2006.

THESIS ABSTRACT

ACCELERATED PRODUCTION OF TREE-FORM CRAPEMYRTLE

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114 Typed Pages

Directed by Gary J. Keever, Ph.D.

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 tree-forms of crapemyrtle with 112 cm to 183 cm of clear trunk, pruning exacerbates the problem by stimulating new shoot formation, often from the main trunk.

The effects of production light level on growth of crapemyrtle were evaluated as a means of accelerating the development of tree-form crapemyrtles. Plant height of ‘Fantasy’, ‘Carolina Beauty’, and ‘Tuscarora’ was greater when grown under 50% or 80% shade than when grown in full sun. Trunk diameter or caliper of Dynamite™

and 'Tuscarora' was greatest when grown in full sun, while production light level had no effect on caliper of 'Carolina Beauty'.

Dynamite™, 'Muskogee', 'Natchez', and 'Tuscarora' grown in Oregon were taller than plants in Alabama, while plants generally had less caliper in Oregon. 'Muskogee' and 'Natchez' in both locations were generally taller when grown under 50% shade than plants in full sun. Caliper of 'Natchez' in both locations was less when plants were grown under shade, while caliper of 'Muskogee' and 'Tuscarora' was not affected by production light level. Flowering of crapemyrtles grown under shade in Alabama was delayed or suppressed in each experiment, while no plants in Oregon flowered the first year of production.

In another study, the effects of production light level on coppicing and coppice timing were evaluated as means of accelerating the development of tree-form crapemyrtles. Coppiced plants were generally taller when grown under lower light levels, while coppicing crapemyrtle while dormant resulted in greater height and stem cross-sectional area than delaying until the growing season, with no effect on survival. Visually, coppiced plants had more uniform shoot diameters and less branching than non-coppiced plants.

Dynamite™ and 'Potomac' grown in tree shelters were taller at the end of two experiments, while caliper was minimally affected. All plants grown in tree shelters flowered later than unsheltered plants and appeared to have straighter, more upright trunks with minimal lateral shoot development.

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TABLE OF CONTENTS

LIST OF TABLES……………………..……………………...…………………….x

LIST OF FIGURES…………..…………...…..……………………..……………..…xii

I. Introduction and Literature Review……………………………..……...………....1

II. Growth Response of Crapemyrtle to Production Light Levels...…………..…....15

III. Growth Response of Crapemyrtle in Different Geographical Areas.…........…….36

IV. Growth Response of Crapemyrtle to Coppicing…………………………………60

V. Growth and Flowering of Crapemyrtle in Response to Tree Shelters………..….82

LIST OF TABLES

Chapter II:

1. Effect of production light level on three container-grown crapemyrtle cultivars in Auburn, AL, experiment 1, 2003…………………………………………………...31

2. Effect of production light level on three container-grown crapemyrtle cultivars in Auburn, AL, experiment 1, 2004…………………………………………………...32

3. Effect of production light level on three container-grown crapemyrtle cultivars in Auburn, AL, experiment 2, 2004……………………………………….……..33

4. Effect of production light level on three container-grown crapemyrtle cultivars in Auburn, AL, experiment 2, 2005……………………………..…………….34

Chapter III:

1. Effect of geographic location and production light level on two container-grown crapemyrtle cultivars, 2004………………………………….………………..55

2. Mean monthly maximum (T_{max}) and minimum (T_{min}) temperatures and monthly rainfall for Auburn, AL and Aurora, OR, respectively during Summer 2004 and 2005.…………………………………………………………………………..56

3. Effect of geographic location and production light level on two container-grown crapemyrtle cultivars, 2004.……………………………………………………..57

4. Effect of geographic location and production light level on two container-grown crapemyrtle cultivars, 2005……………………………………………………58

5. Effect of geographic location and production light level on two container-grown crapemyrtle cultivars, experiment 1, 2005…………………………………......59

Chapter IV:

1. Effects of coppicing and production light level on four container-grown crapemyrtle cultivars in Auburn, AL, experiment 1, 2004……………………....77

2. Effects of coppicing and production light level on flowering of four container-grown crapemyrtle cultivars in Auburn, AL, experiment 1, 2004……………….78

3. Effect of time of coppicing on height and stem area of three container-grown crapemyrtle cultivars in Auburn, AL, experiment 2, 2005………………………79

4. Effect of time of coppicing on floral rating of two container-grown crapemyrtle cultivars in Auburn, AL, experiment 2, 2005……………………………………80

Chapter V:

1. Height and caliper of three container-grown crapemyrtle cultivars grown in Blue-X tree shelters in Auburn, AL, experiment 1, 2004……………...……..…97

2. Height and caliper of three container-grown crapemyrtle cultivars in the year following growth in Blue-X tree shelters in Auburn, AL, experiment 1, 2005….98

3. Height and caliper of two container-grown crapemyrtle cultivars grown in Blue-X tree shelters in Auburn, AL, experiment 2, 2005………………………………...99

4. Flower ratings of two container-grown crapemyrtle cultivars grown in Blue-X tree shelters in Auburn, AL, experiment 2, 2005…………………………………....100

LIST OF FIGURES

Chapter II:

1. Crapemyrtle grown in full sun, under 50% shade, and 80% shade, respectively in Auburn, AL……………………………………………………………………35

Chapter IV:

1. Non-coppiced vs. coppiced crapemyrtle grown in Auburn, AL…………………81

Chapter V:

1. Dynamite™ grown in Blue-X tree shelters in Auburn, AL…………………….....101

2. Dynamite™ with Blue-X tree shelters removed………………………………..102

CHAPTER I

Introduction and Literature Review

Lagerstroemia is native to Southeast Asia, with species in the genus extending as far as India to the west, China and Korea to the north, Japan and the Philippines to the east and Australia to the south (Egolf and Andrick, 1978; Furtado and Montien, 1969). The most familiar are *Lagerstroemia indica*, *Lagerstroemia fauriei*, and hybrids of these two (*L. indica* ×*fauriei*). While *Lagerstroemia* has been cultivated for centuries in its native countries, it was not until the mid 1700's that this genus was introduced to Europe (England) and North America through Charleston, South Carolina (Byers, 1997; Dirr, 1998; Egolf and Andrick, 1978).

Crapemyrtles are valuable landscape species grown in the southern and southwestern U.S. and along the West Coast as shrubs or small trees and are recognized for their excellent seasonal ornamental characteristics. Lengthy summer flowering and diversity of flower colors, plant sizes, and growth habits are appreciated in American landscapes (Cabrera, 2004). The most distinguishing facet of crapemyrtles is their long and terminal or axillary panicles with ruffled flowers in various shades of red, pink, white, lavender, and purple (Cabrera, 2004), which depending on the cultivar, are up to 40 cm (16 in) long and 23 cm (9 in) wide. Crapemyrtles have deciduous undivided simple leaves, mostly opposite or whorled with new growth often appearing bronze. Crapemyrtle leaves can come in a variety of sizes and shades of green in the summer and can have yellow, orange, or red hues in the fall with trunks or stems that are smooth, fluted, and pale to pinkish-brown in color with exfoliating bark (Cabrera, 2004). After the leaves have fallen in the winter, the contorted trunk and branches of the trees scaffolding are exposed, adding a unique element to the landscape. These desirable ornamental traits, coupled with its relatively easy propagation and production, led to the crapemyrtle's wide distribution and use throughout southeastern U.S. landscapes (Cabrera, 2004; Egolf and Andrick, 1978).

The ornamental traits of *Lagerstroemia* have been extensively developed and promoted by U.S. breeding and selection programs, but they have also received significant attention in countries such as France, Italy, Spain, Australia, Japan, Philippines, and India (Cabrera, 2004). Breeding programs over the last 30 years have produced superior forms with a wide range of plant sizes and habits, improved flowering and flower periods, new flower colors, ornamental bark, ornamental foliage, remarkable fall color, disease resistance, and increased vigor (Knox, 2003). Crapemyrtles are very adaptable plants that can range in size from 46 cm (18 in) to 12 m (40 ft) or more and are hardy from USDA cold-hardiness zones 7-9. Crapemyrtles do best in full-sun and moist well drained soils, but can adapt to more diverse climatic and soil conditions.

Crapemyrtles are an economically important nursery crop in both container and field production (USDA, 2004). Deciduous flowering trees, which include crapemyrtle, accounted for 7% of the total gross sales for United States nursery production in 2003 (USDA, 2004). Plants are grown in many sizes from liners to large specimens and may be in production for several years before being marketed. Most cultivars of crapemyrtle are vigorous growers under nursery conditions; however, some cultivars begin flowering as early as May and continue into the fall (Byers, 1997; Knox, 2003). This early flowering characteristic directs plant energy into flowering which can suppress vegetative growth, particularly height growth. Production typically takes place in full sun where flowering is profuse and leads to height suppression which is often compounded by heavy fruit set later in the growing season. In addition, panicles are often large and top-heavy, which results in over-weighted branches that may split trunks during irrigation and promotes blowover 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 suppresses vegetative growth (Morrison et al., 2003). Nursery producers generally strive for straight and unblemished trunks for high-value flowering trees. If terminal inflorescences are removed early, lateral buds can be redirected to the central leader with no deformation of the trunk. However, if terminal inflorescence removal is delayed too long, redirecting a lateral shoot will leave an obvious kink in the trunk long after pruning (several years). The effects of flowering followed by heavy fruit set can result in longer production cycles. For production of standard (single trunk) or multi-trunk (usually three) tree-forms of crapemyrtle with 112 cm (4 ft) to 183 cm (6 ft) of clear trunk, pruning exacerbates the problem by stimulating new shoot formation, often from the main trunk.

Fain et al. (2001) determined the effect of two plant growth regulators, Pistill [(ethephon) Monterey Chemical, Fresno, CA] and Atrimmec [(dikegulac-sodium) PBI/Gordon, Kansas City, MO] on flower abortion, fruit set, and axillary shoot stimulation of ‘Tuscarora’ crapemyrtle when applied to open inflorescences. As low as 2% fruit set was achieved with a single application of Pistill at 1000 ppm during full flower. Pistill similarly caused a significant decrease in fruit set compared to the control. Atrimmec did not affect flower abortion and only slightly reduced fruit set. Application of Pistill at full flower was an effective tool to induce flower abortion resulting in reduced fruit set. However, Pistill was not effective on inflorescences that opened and had begun to set fruit before application or ones that had not begun to open at the time of application, therefore it was determined that multiple applications would be necessary to cause flower abortion. Applications of Pistill also increased lateral branching, but not plant height. A later study determined the effect of multiple applications of Pistill on flower abortion and subsequent axillary shoot growth in ‘Tuscarora’ crapemyrtle when applied to open inflorescences before fruit set (Morrison et al., 2003). Foliar applications of 1000 ppm Pistill applied at 7-day intervals during flowering and directed towards developing inflorescence resulted in up to 96% flower abortion and greatly increased axillary shoot formation. These results suggested multiple applications of Pistill may be useful in enhancing quality of crapemyrtles, due to noticeably fuller plants, but overall plant height was minimally affected.

There are three major mechanisms that can control the development of tree form: apical dominance can affect both the patterns and orientation of axes development; allocation mechanisms that maintain feedbacks between leaf and wood production for both transport capacity and mechanical support; and shading that reduces light intensity (Wilson, 1990). Apical dominance is the control exerted by the apical portions of the shoot over the outgrowth of lateral buds (Cline, 1991). The influence of light on apical dominance can be dramatic; the higher the light intensity the weaker the apical dominance (Anderson, 1976; Kohyama, 1980). Leaf shading enriches the far-red component of the transmitted light and causes a reduction of the fluence rate (irradiance) and light quality (Deregibus et al., 1983). Shading reduces photosynthesis and eventually reduces 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 (Wilson, 1990). Far-red light inhibits the initiation of bud outgrowth and also enhances subsequent bud elongation after it has been initiated (Morgan and Smith, 1986; Tucker and Mansfield, 1972). This upward growth can be useful in obtaining tree-form crapemyrtles.

Vegetative growth and flowering are thought to be regulated by several factors including photoperiod, accumulated light intensity, and temperature (Rawson and Harkess, 1997). Growth often depends on the interaction between environmental and genetic factors (Loreti and Pisani, 1990) and manipulation requires an understanding of these factors for each species. Crapemyrtles prefer hot, sunny climates where flowering is profuse and, thus, are ideally suited for southern and southwestern regions of the U.S. (USDA Cold Hardiness Zones 7-9). Western regions of Oregon and Washington are in USDA Zones 7 and 8; however, crapemyrtles are not commercially grown to any extent and are rarely planted in landscapes because flowering is sporadic, if at all. The consensus is although these environments have sufficient sunlight, moderate winters, and adequate moisture, they lack the hot weather found in the southern U.S. where flowering is prolific (Byers, 1997). High temperatures favor rapid floral bud initiation and development in dwarf crapemyrtles (Guidry, 1977), while heavy shade suppresses flowering and axillary shoot growth (Wilson, 1990; Wade and Woodward, 2001). While detrimental from a landscape perspective, climate and shade-induced flower suppression may create growing opportunities for wholesale nurseries.

The value of woody landscape plants is generally dictated by size (i.e., height and spread), and nursery growers favor practices that maximize growth (Cabrera and Devereaux, 1998). Coppicing, cutting trees to the ground to encourage vigorous regrowth, often results in straight trunks with little lateral branching. Sprouts may grow more rapidly in height and biomass than shoots of intact plants, although the causes of this growth stimulation are not known (Kruger and Reich, 1993). Hypotheses regarding the nature of this rapid regrowth often focus on the abundant resources afforded to sprouts by a relatively large root system (Radosevich and Conrad, 1980; Tschaplinski and Blake, 1989). Increased leaf photosynthetic productivity of coppiced red oak (*Quercus rubra*) helped offset the loss of plant mass and internal resources resulting from coppicing (Kruger and Reich, 1993). Coppicing of young Chinese pistache (*Pistacia chinensis*) increased the number of marketable trees with straight trunks (Miles et al., 2001), a highly desirable response in tree-form crapemyrtle production. Biomass was reported to be maximized by coppicing during the dormant season and minimized by cutting during active growth (Hardesty et al., 1988; Smith, 1986). Coppicing of red oak while actively growing led to substantial differences in net relative growth, in terms of biomass, compared to dormant coppicing, due to alterations in leaf gas exchange largely through coppice-induced changes in leaf-root balance (Kruger and Reich, 1993). While practiced in shade tree nurseries in the Northwest and other regions of the U.S. on other species, coppicing is not typically used in the production of tree-form crapemyrtles.

Another aspect of enhanced growth involves the use of tree shelters, which are translucent polypropylene tubes of various height [usually 60 to 150 cm (24 to 60 in)] placed around tree seedlings or transplants at planting time (Burger et al., 1992). Tree shelters can create a beneficial microclimate within the shelter of increased humidity and CO_2 levels and reduced drying and mechanical injury from wind (Frearson and Weiss, 1987). First available in the United States in 1989, tree shelters have accelerated the growth of some tree species (Svihra et al., 1993; West et al., 1999). Shelters typically increase survival and height growth, but effects differ among species (Potter, 1991). Increased temperature, humidity and CO_2 concentration within tree shelters have all been suggested as probable causes for the increased growth (Svihra et al., 1993). The nature of the relationship between these environmental factors and their potential effect on plants grown in tree shelters is unclear.

Kjelgren et al. (2000), in studying water relations of container grown Kentucky coffee tree (*Gymnocladus dioica*) in translucent plastic shelters, reported increased air temperature, vapor pressure, and 70% less solar radiation, suggesting that trees respond to shelters as they do shade. Height increases of 60% to 600% from using tree shelters have been reported (Svihra et al., 1993). Tree shelters tend to prolong the growing season for seedlings, giving them more degree-days in which to grow (Minter et al., 1992). Shelters can typically increase height growth but often reduce the rate of trunk diameter growth which may result in trees without enough structural support to stand upright. Effects on diameter growth are species specific and can be positive or negative (Potter, 1991). West et al. (2002) reported that after three growing seasons in shelters there was no difference in diameter growth between sheltered and unsheltered trees for all 11 tree species tested. The magnitude of height increases and caliper decreases that generally are caused before trees emerge from shelters can differ greatly among species (Gerhold, 1999). Generally the greatest increases in height and decreased caliper growth occur in the first 2 years, after which the shelters should be removed (Gerhold, 1999). Tree shelters have been widely used in Great Britain and other countries to cut costs of establishing small forest trees, and Svihra et al. (1993) speculated they could be broadly used in nurseries and landscapes. Height growth of containerized Southern magnolia (*Magnolia grandiflora*), holly oak (*Quercus ilex*), and deodar cedar (*Cedrus deodara*) was accelerated in tree shelters with no significant effect on caliper (Svihra et al., 1993). Jones et al. (1996), in studying the use of plastic tree shelters for low-cost establishment of street trees, found that survival along with height and caliper growth of all species tested in shelters equaled or exceeded that of plants grown without shelters.

Blue-X tree shelters (McKnew Enterprises, Elk Grove, CA) are fabricated from partially transparent blue-tinted polyester film which reportedly amplifies blue light and reduces UV light within the shelter. According to the manufacturer, the amplified blue light increases photosynthetically active radiation resulting in increased trunk diameter, in addition to enhanced transplant survival and accelerated growth in height.

For production of a standard (single trunk) or multi-trunk (usually three) tree-form crapemyrtle with 112 cm (4 ft) to 183 cm (6 ft) of clear trunk, plant growth regulators were proven ineffective (Fain et al., 2001 ;Morrison et al., 2003). The plant growth regulators were effective in aborting flowers; however they minimally affected plant height and also increased lateral and axillary shoot formation. By using a combination of environmental manipulations and cultural methods such as production light level, nutrition, climate, tree shelters, and coppicing, it may be possible to accelerate the production of tree-form crapemyrtles.

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CHAPTER II

Growth Response of Crapemyrtle to Production Light Levels

Abstract

The effects of production light level on growth of crapemyrtle were evaluated as a means of accelerating the development of tree-form crapemyrtles. 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 was greater than that 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 plants 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 of 'Tuscarora' previously grown under 80% shade compared to plants grown in full sun.

Index words: container production, production light level.

Species used in this study: 'Tuscarora' (*Lagerstroemia indica* L. ×*fauriei* Koehne), 'Fantasy' (*Lagerstroemia fauriei*), 'Whitt 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 cm (4 ft) to 183 cm (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 delay flowering and accelerate height growth, while minimally affecting caliper. Plants developed sufficient clear trunk height the first season so that head development rather than additional height can be focused on 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, grown in the southern and southwestern U. S. and along the West Coast as shrubs or small trees, are valuable landscape species and are recognized for their exceptional seasonal ornamental characteristics. Lengthy summer flowering and diversity of flower colors, plant sizes, and growth habits are appreciated by horticulturalist and gardeners (3). Crapemyrtles are an economically important crop in both container and field production. Breeding programs over the last 30 years have produced superior forms with a wide range of plant sizes and habits, improved flowering, new flower colors, ornamental bark, ornamental foliage, disease resistance and increased vigor (9). Crapemyrtles are grown in many sizes from liners to large specimens and may be in production for several years before being marketed. 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 characteristics direct plant energy into flowering which 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 top-heavy, which causes over-weighted branches during irrigation that may split trunks and promote blowover 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 (12). For production of standard (single trunk) or multi-trunk (usually three) tree-forms of crapemyrtle with 112 cm (4 ft) to 183 cm (6 ft) of clear trunk, pruning exacerbates the problem by stimulating new shoot formation, often from the main trunk. Fain et al. (2001) determined the effect of two plant growth regulators, Pistill [(ethephon) Monterey Chemical, Fresno, CA] and Atrimmec [(dikegulac-sodium) PBI/Gordon, Kansas City, MO] on flower abortion, fruit set, and axillary shoot stimulation of 'Tuscarora' crapemyrtle when applied to open inflorescences. As low as 2% fruit set was achieved with a single application of Pistill at 1000 ppm at full flower. Pistill similarly caused a significant decrease in fruit set compared to the control. Atrimmec did not significantly affect flower abortion and only slightly reduced fruit set. Application of Pistill at full flower was an effective tool to induce flower abortion resulting in reduced fruit set. However, Pistill was not effective on inflorescences that opened and had begun to set fruit before or after application. Applications of Pistill also increased lateral branching, but not an increase in plant height. A later study determined the effect of multiple applications of Pistill on flower abortion and subsequent axillary shoot growth in 'Tuscarora' crapemyrtle when applied to open before fruit set (12). Foliar applications of 1000 ppm Pistill applied at 7-day intervals during flowering and directed towards developing inflorescence resulted in up to 96% flower abortion and greatly increased axillary shoot formation. These results suggested multiple applications of Pistill may be useful in enhancing quality of crapemyrtles, due to noticeably fuller plants, but overall plant height was minimally affected.

There are three major mechanisms that can control the development of tree-form: apical dominance can affect both the patterns and orientation of axes development; allocation mechanisms that maintain feedbacks between leaf and wood production for both transport capacity and mechanical support; and shading that reduces light intensity (19). Apical dominance is the control exerted by the apical portions of the shoot over the outgrowth of lateral buds (5). The influence of light on apical dominance can be dramatic; the higher the light intensity the weaker the apical dominance (1, 10). Leaf shading enriches the far-red component of the transmitted light and causes a reduction of the fluence rate (irradiance) and light quality (6). Shading reduces photosynthesis and eventually reduces 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.

Vegetative growth and flowering are thought to be regulated by several factors including photoperiod, accumulated light intensity, and temperature (14). High temperatures favor rapid floral bud initiation and development in dwarf crapemyrtles (8), while heavy shade will suppress 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 will maximize growth (4). Therefore, the objective of this study was to evaluate the effect of production light level on vegetative growth during nursery production of tree-form crapemyrtle. Additionally, supplemental topdressed fertilizer was tested.

Materials and Methods

Experiment 1. Research was conducted outdoors under nursery conditions at Auburn University's Paterson Horticultural Complex in Auburn, AL, to determine how three light regimes affect vegetative growth. Same-source rooted, 10.2 cm (4 in) liner pots of *Lagerstroemia indica* 'Carolina Beauty' and *Lagerstroemia fauriei* 'Fantasy' were repotted in fall of 2002 into 11.4 L (#3) pots containing an 8:1 (by vol) pinebark:sand substrate 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. *Lagerstroemia indica* ×*fauriei* 'Tuscarora' was repotted from 10.2 cm (4 in) liner pots to 3.8 L (#1) using the same substrate in spring of 2003. 'Carolina Beauty' and 'Fantasy' were pruned to 59 cm (23 in) and one-half of the plants were topdressed with 70 g (2.5 oz) of the same fertilizer used in the substrate mix on July 15, 2003. One-half of 'Tuscarora' [30 cm (12 in)] was topdressed with 40 g (1.4 oz) on the same date. Plants were spaced 0.6 m (2 ft) apart in full sun, under 50% or 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' 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 average length of the three longest shoots, measured from the base of the shoot to the tip, were measured in August, September, and October, 2003.

‘Carolina Beauty’ and ‘Fantasy’ were repotted into 38 L (#10) pots and ‘Tuscarora’ into 11.4 L (#3) pots containing the previously described substrate on December 12, 2003. All shoots, except the three previously measured, were removed on February 24, 2004. Plants remained under the three light regimes during the second year of the experiment and one-half of the plants in 38 L (#10) pots and 11.4 (#3) pots under each light regime were topdressed on June 16, 2004, with 180 g (6.3 oz) and 70 g (2.5 oz), respectively, of the same 12-month release fertilizer that was used in the substrate mix. Height and length of the three longest shoots were measured bi-monthly from April to October.

Experiment 2. Lagerstroemia indica ‘Carolina Beauty’ and ‘Whit II’ Dynamite™ and *Lagerstroemia indica ×fauriei* ‘Tuscarora’ were used in a repeat experiment. On March 16, 2004, 60 plants of each cultivar were repotted from 10.2 cm (4 in) liner pots into 11.4 L (#3) pots [‘Tuscarora’, 21 cm (8.3 in) tall and Dynamite™, 11 cm (4.3 in) tall] and 3.8 L (#1) pots [‘Carolina Beauty’ 12 (4.7 in) tall] containing the previously described substrate. 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 in each light regime were topdressed with the same fertilizer previously used on June 16, 2004, with 40 g (1.4 oz) [3.8 L (#1) pots] or 70 g (2.5 oz) [11.4 L (#3) pots]. 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 bi-monthly April to October.

In the second year of the experiment, 'Carolina Beauty' was repotted on February 18, 2005, into 11.4 L (#3) pots containing the previously described substrate. Dynamite™ and 'Tuscarora' remained in 11.4 L (#3) pots. All plants were placed in full sun on March 17, 2005, and the supplemental topdress treatments were discontinued, with each cultivar having treatments consisting of the three of previous production light levels. Height and caliper were recorded bi-monthly April to October. Data were subjected to analysis of variance using SAS statistical software package (15) and means were separated using Duncan's Multiple Range Test (α= 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' was 21% taller in October when grown under 80% shade, 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. There were no treatment-related differences in shoot length of 'Carolina Beauty' at any data collection.

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 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. Shoot length of 'Fantasy' remained longest in April and June when grown under 80% shade. Shoot length of these plants was similar to that of plants under 50% shade, but 49% and 40% greater than that 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% 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.

There was no growth effect on any cultivar tested due to additional topdressed fertilizer. Speculation is the 12-month release fertilizer used in this experiment released at a rate too slow to cause measurable differences (data not shown). Plants of each cultivar were analyzed by combining the treatments under each light regime.

Experiment 2. Height of ‘Tuscarora’ grown under 80% shade, was 14% greater than that of plants under 50% shade and similar to plants in full sun in April. In June, plants in full sun were 22% taller than plants under 80% shade and similar to plants under 47% shade (Table 3). Higher light intensity and concomitant increased temperature in full 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 in August and October, respectively, than that of plants in full sun. 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 in August and October, respectively, than plants in full sun. 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, 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 were no treatment effects due to the addition of supplemental topdressed fertilizer on any cultivar tested, possibly due to the slow release rate (data 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 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 (Table 4). Height of ‘Tuscarora’ previously grown under the three light regimes was similar thereafter. Similar to ‘Tuscarora’, height of ‘Carolina Beauty’ was greater for plants previously grown under shade in April and 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' remained greater in full sun than that of plants under 80% shade in the second year, however plants previously grown under 50% shade that had 21% less caliper by the end of the first season, were similar to plants in full sun at each data collection (Table 4). 'Carolina Beauty' caliper was similar across previous production light levels throughout the growing season. Similar to 'Tuscarora', caliper of Dynamite™ in full sun was 61% and 49% greater in April and June, respectively, than that of plants previously grown under 50% shade which was similar to that of plants under 80% shade. Calipers in August and October were similar for Dynamite™ previously grown under the three production light levels.

In a spectacular culmination of an elegant series of experiments, height growth of all cultivars, except Dynamite™, was generally greater when grown under shade. 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. Shoots of 'Fantasy' and 'Tuscarora' grown under 80% shade were longer by the end of the first growing season than those of plants grown in full sun and under 50% shade. Caliper was generally greater in full sun, except for 'Carolina Beauty' in October 2004, when calipers were similar under the three light regimes. 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 increase in caliper when grown in full sun the second year along with the height advantage gained from growing under lower light levels may benefit tree-form crapemyrtle production. Plants developed sufficient clear trunk height the first season so that head development rather than additional height could be focused upon in subsequent production years. (Figure 1). Results of this study suggest growing plants under lower light levels during container production can accelerate the development of tree-form crapemyrtle. The suppression or delayed flowering under lower production light levels can lead to increased growth throughout the growing season resulting in the necessary structure for further development into tree-form crapemyrtles.

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

Light regime	Height (cm)			Shoot length (cm)[z]		
	'Tuscarora'					
	Aug.	Sept.	Oct.	Aug.	Sept.	Oct.
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'					
	Aug.	Sept.	Oct.	Aug.	Sept.	Oct.
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'					
	Aug.	Sept.	Oct.	Aug.	Sept.	Oct.
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]Combined means of topdress treatments separated by Duncan's Multiple Range Test, $\alpha = 0.05$.

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

Light regime	Height (cm)				Shoot length (cm)[z]			
'Tuscarora'	Apr.	June	Aug.	Oct.	Apr.	June	Aug.	Oct.
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'	Apr.	June	Aug.	Oct.	Apr.	June	Aug.	Oct.
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'	Apr.	June	Aug.	Oct.	Apr.	June	Aug.	Oct.
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]Combined means of topdress treatments separated by Duncan's Multiple Range Test, $\alpha = 0.05$.

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

Light regime	Height (cm)				Caliper (mm)			
	'Tuscarora'							
	Apr.	June	Aug.	Oct.	Apr.	June	Aug.	Oct.
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'							
	Apr.	June	Aug.	Oct.	Apr.	June	Aug.	Oct.
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™							
	Apr.	June	Aug.	Oct.	Apr.	June	Aug.	Oct.
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]Combined means of topdress treatments separated by Duncan's Multiple Range Test, $\alpha = 0.05$.

Table 4. Effects of light level on three container-grown crapemyrtle cultivars^z in Auburn, AL, experiment 2, 2005.

Light regime	Height (cm)				Caliper (mm)			
	'Tuscarora'							
	Apr.	June	Aug.	Oct.	Apr.	June	Aug.	Oct.
Sun	84.0b	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'							
	Apr.	June	Aug.	Oct.	Apr.	June	Aug.	Oct.
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™							
	Apr.	June	Aug.	Oct.	Apr.	June	Aug.	Oct.
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}All plants grown in full sun during the second growing season, 2005.

^{y}Means separated by Duncan's Multiple Range Test, $\alpha = 0.05$.

Figure 1. Crapemyrtle grown in full sun, under 50% shade, and 80% shade, respectively in Auburn, AL.

CHAPTER III

Growth Response of Crapemyrtle in Different Geographical Areas

Abstract

The effects of geographic location and production light level on vegetative growth of crapemyrtle were evaluated as a means of accelerating the development of tree-form crapemyrtles. By the end of the first year of the experiment, Dynamite™, ‘Muskogee’, ‘Natchez’, and ‘Tuscarora’ grown in Oregon were as much as 42%, 51%, 43%, and 92% taller, respectively, than plants in Alabama, while plants generally had less caliper in Oregon. ‘Muskogee’ and ‘Natchez’ in both locations and ‘Tuscarora’ in Alabama were generally taller when grown under 50% shade than plants in full sun, while height of Dynamite™ was not affected by production light level. Caliper of ‘Natchez’ in both locations and of Dynamite™ in Alabama was less when plants were grown under shade, while caliper of ‘Muskogee’ and ‘Tuscarora’ was not affected by production light level. Flowering of plants grown under shade in Alabama was delayed, while no plants in Oregon flowered the first year. In the second year of the experiment, when all plants were grown in full sun, all cultivars continued to be taller in Oregon, while caliper remained greater in Alabama. The height advantage gained from growing plants under shade the previous year was not evident in any cultivar by the end of the second year, while caliper was similar for all cultivars previously grown in full sun and 50% shade.

There was no difference in flowering of plants in Alabama previously grown under 50% shade and in full sun, while 50% to 100% of the four cultivars in Oregon flowered with no obvious difference due to prior production light level.

Index words: container production, production light level, climatic comparisons.

Species used in this study: 'Muskogee', 'Natchez', and 'Tuscarora' crapemyrtle (*Lagerstroemia indica* L. ×*fauriei* Koehne) and 'Whitt II' (Dynamite™) crapemyrtle (*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 a reduction in vegetative growth, particularly height growth. Crapemyrtles prefer hot, sunny climates where flowering is profuse and, thus, are ideally suited for southern and southwestern regions of the U.S. (USDA Cold Hardiness Zones 7-9). Western regions of Oregon and Washington are in USDA Zones 7 and 8; however, crapemyrtles are rarely planted in landscapes and flower sporadically, if at all. Lower production light levels along with geographic location may suppress flowering and promote more height growth in a single season. 'Muskogee' and 'Natchez' in both locations and 'Tuscarora' in Alabama were generally taller when grown under 47% shade than plants in full sun, while height of Dynamite™ was not affected by production light level. Caliper of 'Natchez' in both locations and of Dynamite™ in Alabama was less when plants were grown under shade, while caliper of ‘Muskogee’ and ‘Tuscarora’ was not affected by production light level. By growing all plants in full sun the second year it was possible to regain caliper lost due to growth under shade the previous year although some of the height advantage gained from growing under shade decreased. However, plants developed sufficient clear trunk height the first season so that head development rather than additional height would be more important during the second season. Growing plants in Oregon or similar USDA zones in the region can be beneficial to the development of tree-form crapemyrtle. All cultivars were taller in Oregon although caliper was greater in Alabama. The suppression or lack of flowering in Oregon can lead to increased growth throughout the growing season resulting in the necessary structure for further development into tree-form crapemyrtles.

Introduction

Crapemyrtles, grown in the southern and southwestern U. S. 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 diversity of flower colors, plant sizes, and growth habits are appreciated by horticulturalist and gardeners (3). Crapemyrtles are an economically important crop in both container and field production (18). Breeding programs over the last 30 years have produced superior forms with a wide range of plant sizes and habits, improved flowering, new flower colors, ornamental bark, ornamental foliage, disease resistance and increased vigor (9). Crapemyrtles are grown in many sizes from liners to large specimens and may be in production for several years before being marketed. 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). This early flowering characteristic can result in less vegetative growth, particularly height growth. Height suppression is 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 cm (4 ft) to 183 cm (6 ft) of clear trunk, pruning exacerbates the problem by stimulating new shoot formation, often from the main trunk. Fain et al. (2001) determined the effect of two plant growth regulators, Pistill [(ethephon) Monterey Chemical, Fresno, CA] and Atrimmec [(dikegulac-sodium) PBI/Gordon, Kansas City, MO] on flower abortion, fruit set, and axillary shoot stimulation of ‘Tuscarora’ crapemyrtle when applied to open inflorescences. As low as 2% fruit set was achieved with a single application of Pistill at 1000 ppm at full flower. Pistill similarly caused a significant decrease in fruit set compared to the control. Atrimmec did not significantly affect flower abortion and only slightly reduced fruit set. Application of Pistill at full flower was an effective tool to induce flower abortion resulting in reduced fruit set. However, Pistill was not effective on inflorescences that opened and had begun to set fruit before or after application. Applications of Pistill also increased lateral branching, but not an increase in plant height. A later study determined the effect of multiple applications of Pistill on flower abortion and subsequent axillary shoot growth in ‘Tuscarora’ crapemyrtle when applied to open flowers before fruit set (12). Foliar applications of 1000 ppm Pistill applied at 7-day intervals during flowering and directed towards developing inflorescences resulted in up to 96% flower abortion and greatly increased axillary shoot formation. These results suggested multiple applications of Pistill may be useful in enhancing quality of crapemyrtles, due to noticeably fuller plants, but overall plant height was minimally affected.

There are three major mechanisms that can control the development of tree-form: apical dominance can affect both the patterns and orientation of axes development, allocation mechanisms that maintain feedbacks between leaf and wood production for both transport capacity and mechanical support, and shading that reduces light intensity (19). Apical dominance is the control exerted by the apical portions of the shoot over the outgrowth of lateral buds (4). The influence of light on apical dominance can be dramatic; the higher the light intensity the weaker the apical dominance (1, 10). Leaf shading enriches the far-red component of transmitted light and causes a reduction of the fluence rate (irradiance) and light quality (6). Shading reduces photosynthesis and eventually reduces 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.

Crapemyrtles prefer hot, sunny climates where flowering is profuse and, thus, are ideally suited for southern and southwestern regions of the U.S. (USDA Cold Hardiness Zones 7-9). Western regions of Oregon and Washington are in USDA Zones 7 and 8; however, crapemyrtles are not commercially grown to any extent and are rarely planted in landscapes because flowering is sporadic, if at all. The consensus is although these environments have good sunlight during the growing season, moderate winters, and adequate moisture, they lack the high summer temperatures typical of the South where crapemyrtle flowering is prolific (2). Vegetative growth and flowering are thought to be regulated by several factors including photoperiod, accumulated light intensity, and temperature (14). High temperatures favor rapid floral bud initiation and development in dwarf crapemyrtles (8). While detrimental from a landscape perspective, lack of flowering in these regions may create growing opportunities for wholesale nurseries. In addition, high levels of fertilizers, especially nitrogen (N), stimulate vegetative growth and may reduce flowering. Growth often depends on the interaction between environmental and genetic factors (11). Therefore, the objective of this study was to evaluate how geographic location and production light level affect vegetative growth during nursery production of tree-form crapemyrtle. Additionally, supplemental topdressed fertilizer was tested.

Materials and Methods

Research was conducted outdoors at Auburn University's Paterson Horticultural Complex in Auburn, AL and at Oregon State University's North Willamette Research & Extension Center in Aurora, OR. Same-source, uniform liners of *Lagerstroemia indica* 'Whitt II' (Dynamite™) and *Lagerstroemia indica ×fauriei* 'Muskogee', 'Natchez', and 'Tuscarora' were used in this experiment. Plants in Alabama were potted on March 18, 2004, from 10.2 cm (4 in) liner pots into 11.4 L (#3) pots containing an 8:1 (by vol) pinebark:sand substrate 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. Plants in Oregon were potted on the same date into same size containers with 100% Douglas fir bark substrate screened to be less than 2.2 cm (0.8 in) and amended as in Alabama. Plants were spaced 0.6 m (2 ft) apart in full sun and under 50% shade and watered with overhead impact sprinklers as needed. The shade treatment was obtained by covering structures in Alabama [4.3 m H (14 ft) × 31.7 m L (104 ft) × 3.7 m W (12 ft)] and Oregon [3.7 m H (12 ft) × 10 m L (33 ft) × 10 m W (33 ft)] with a single layer of 47% shade fabric. All trees were held upright by 152 cm (60 in) bamboo stakes, and all lateral branches were removed weekly. Height and caliper were recorded monthly from June to October. Height was measured from the substrate surface to the uppermost part of the plant and caliper was measured 2.5 cm (1 in) from the substrate surface. One-half of the plants in each light regime were topdressed on June 16, 2004, with 70 g (2.5 oz) of the same 12-month release fertilizer that was used in the substrate mix. In the second year of the experiment, plants receiving topdressed fertilizer were discarded and the remaining plants were transplanted into 26.5 L (#7) containers. All plants were grown in full sun. Meteorological variables of daily maximum and minimum air temperatures and rainfall were collected at each geographic location and averaged for each month.

The experiment was an unreplicated split-split plot design with geographic location (Alabama and Oregon) as the main plot, light (full sun and 47% shade) as a split-plot, and fertilizer (+/- topdress) as a split-split plot. Treatments were randomized within cultivar with 10 single plant replicates per cultivar which equaled 80 plants per cultivar. Because fertilizer had no effect on growth or flowering in 2004 it was removed from the ANOVA and not included as a treatment in 2005. In the second year with the fertilizer treatments removed, the experiment was a split-plot design with 40 plants per cultivar.

Data were analyzed using analysis of variance (ANOVA) to test main effects and interactions (16).

Results and Discussion

Dynamite™. Height of Dynamite™ was 172% and 40% greater in Alabama in June and July, but was surpassed in August and later data collection dates by plants grown in Oregon (Table 1). By the end of the growing season, plants in Oregon were 42% taller than those in Alabama. The greater height growth of plants in Alabama in June may be due in part to higher spring temperatures. In April and May, average monthly minimum temperatures were 10.9 and 17.8C (51.6 and 64.0F) compared to 5.8 and 9.3C (42.4 and 48.74) in Oregon (Table 2). Previous research has shown that growth of dwarf crapemyrtles was greater at higher minimum night temperatures (8). However, between June and October, plants in Oregon increased in height by 444% compared to 41% for Alabama. Differences in growth rate are thought to be linked to flowering. Forty percent, 50%, 80%, and 100% of Dynamite™ in Alabama were flowering or had flowered in July, August, September, and October, respectively, while none flowered in Oregon. Between August and October, plants in Alabama increased in height by only 5.9 cm (2.3 in) compared to 18.2 cm (7.2 in) for plants in Oregon. Plants in Oregon continued to grow vegetatively until they were exposed to several hard freezes in the fall. Flowering of crapemyrtle slows vegetative growth, especially height growth, and may be the reason for the continued increase in height of plants in Oregon. Plant height was not affected by production light levels.

Caliper of Dynamite™ in full sun was greater in Alabama than Oregon throughout the season, but decreased from 102% to 10% greater from June to October, respectively. Plants grown under 50% shade had 146%, 61%, and 25% more caliper in June, July, and August, respectively, in Alabama, but was similar thereafter to their Oregon counterparts. Similar to height, the greater caliper in Alabama in June can be attributed to the higher minimum temperatures in Alabama in April and May. The caliper advantage of plants in Alabama decreased as plant height in Oregon increased, probably due to the lack of flowering of plants in Oregon. Caliper of plants grown in Alabama in full sun was greater than that of plants under 50% shade at all data collections, with 14% greater caliper by the end of the growing season. Caliper of Oregon plants was not affected by production light level at any data collection.

An earlier start of the second growing season in Alabama (Table 2), when all plants were grown in full sun, may have allowed for the height advantage gained by growing plants in Oregon the previous year to decrease to negligible in June and August. Similar to 2004, higher spring minimum temperatures in Alabama allowed for more early growth than in Oregon. However, height of Dynamite™ in Oregon was 44% taller than plants in Alabama by the end of the second growing season (Table 4). Similar to the first year, plants in Oregon had 76% more height growth from June to October than plants in Alabama. All plants of Dynamite™ in Alabama had flowered by October, compared to 63% in Oregon. Again, flower suppression in Oregon may have allowed for increased height growth throughout the growing season compared to Alabama. Caliper of Alabama-grown Dynamite™ remained greater at each data collection than plants grown in Oregon, again, probably due to the higher spring temperatures in Alabama (Table 2).

Height and caliper were similar in Alabama and Oregon between production light levels in the second year of the experiment when all plants were grown in full sun. Plants in Alabama regained the caliper lost from growing under the shade the previous year.

'Tuscarora'. There were interactions between geographic location and production light level for height of 'Tuscarora' at all data collection dates (Table 1). Location effects were similar in sun and shade and similar to Dynamite™. Height of 'Tuscarora' in full sun was greater in Alabama in June, similar in July, and greater in plants in Oregon thereafter. Alabama plants in full sun were 115% taller in June, while plants in Oregon were 71%, 117%, and 142% taller in August, September, and October, respectively. Similar to Dynamite™, greater height growth of Oregon plants from June to October, can be attributed to moderate spring and summer temperatures and lack of flowering. Alabama-grown plants in full sun had all flowered by August, while none flowered in Oregon. Similar to plants in full sun, plants grown under shade were taller in Alabama until surpassed by Oregon plants in August. By the end of the growing season, 'Tuscarora' under shade in Oregon was 60% taller than plants under shade in Alabama. 'Tuscarora' grown in Alabama was taller under 50% shade than when grown in full sun. Plant height under shade increased from 28% greater in June to 56% greater than plants grown in full sun in October. Increased height growth under shade is probably due to the enriched far-red light, which enhances shoot elongation (6, 13, 17). In full sun 80% and 100% of plants were flowering by July and August, while 50% and 75% of plants grown under shade were flowering. Greater flowering of the terminal shoots, which suppresses shoot elongation (7, 12), may have further contributed to height differences observed in

full sun and under shade. Similar to Dynamite™, production light level in Oregon had no effect on plant height.

Caliper of ‘Tuscarora’ in Alabama was greater than that of plants in Oregon at each data collection until October, when calipers were similar. Caliper differences decreased from 216% greater in June to 13% greater in September, a trend similar to Dynamite™. The large differences in caliper in June may be explained by the higher spring temperatures in Alabama allowing for more growth early in the season compared to Oregon.

In the second year of the experiment, when all plants were grown in full sun, ‘Tuscarora’ in Oregon was 32% and 18% taller in June and October, respectively, than plants in Alabama but similar in August (Table 4). By August, 100% of plants in Alabama and 83% in Oregon had flowered. Similar to the previous year, flower suppression may have caused increased height growth of plants in Oregon. There was no obvious difference in flowering between plants previously grown under the two production light levels within Alabama or Oregon. Only in June were plants previously grown under shade in both locations significantly taller than plants in sun. Caliper remained greater for ‘Tuscarora’ in Alabama than that of plants in Oregon, as much as 36% by the end of the growing season. Interestingly, caliper of plants previously grown under shade in both locations was 5% and 8% greater than plants grown in full sun both years in October.

‘*Natchez*’. Similar to Dynamite™ and ‘Tuscarora’, ‘Natchez’ in Alabama responded to higher spring temperatures with increased shoot growth (Table 2). ‘Natchez’ in Alabama was 133% and 42% taller than plants in Oregon in June and July

(Table 3). However, as the growing season progressed, ‘Natchez’ in Oregon overcame lower spring temperatures and were taller than plants in Alabama in August and at later data collections. By the end of the growing season, plants in Oregon were 43% taller than those in Alabama, and plants grown under shade in both locations were 16% taller than plants in full sun. Similar to Dynamite™ and ‘Tuscarora’, no plants in Oregon flowered, which may have led to increased shoot elongation. There was an interaction between location and production light level for plant height in August and September. Oregon plants grown in full sun were taller in August and September than plants in Alabama, while plants in shade were 23% taller in Oregon in September. In August, 65% of Alabama plants in full sun and 10% of plants under shade were flowering, while no flowering occurred in Oregon. Plants in Alabama grown under shade in August and September were 43% and 40% taller, respectively, than plants in full sun while plants in Oregon were similar in height in both light regimes.

Caliper was greater throughout the growing season for plants grown in Alabama than in Oregon, regardless of production light level, although differences lessened as the season progressed. Plants in full sun in Alabama had 27%, 25%, and 12% greater caliper in June, July, and August, respectively, than plants grown under shade, while there was no difference between production light levels in Oregon. Also, plants grown in full sun had 9% and 10% greater caliper in September and October, respectively, than plants grown under shade at the two locations.

In the second year of the experiment, ‘Natchez’ in Oregon continued to be taller than plants in Alabama. Prior production light level had no effect on height in 2005, except in August when plants previously grown under shade were 12% taller than plants grown in full sun (Table 5). By the end of the growing season 100% of the plants in both locations had or were flowering. Similar to the previous season, caliper was greater in Alabama for plants grown in full sun and under shade throughout the 2005 growing season. There was no caliper difference in Alabama between the two light regimes in June and August. However, caliper of ‘Natchez’ in Oregon previously grown under shade was 20% and 15% greater in June and August, respectively, than that of plants in full sun.

‘*Muskogee*’. Similar to Dynamite™, ‘Natchez’, and ‘Tuscarora’, ‘Muskogee’ responded to higher spring temperatures in Alabama with increased growth early in the season compared to plants in Oregon (Table 2). Overall height of ‘Muskogee’ in Oregon surpassed those grown in Alabama in September, with plants being as much as 66% and 75% taller in September and October, respectively (Table 3). Similar to the other cultivars, the increased height growth in Oregon was probably due to the lack of flowering. In Alabama, 20%, 43%, and 95% of ‘Muskogee’ were or had flowered in August, September, and October, respectively, while none flowered in Oregon. Plants grown under 50% shade were generally taller in both locations than plants grown in full sun throughout the season and were 27% taller in October. Similar to ‘Tuscarora’, caliper was 164% greater in Alabama when measured in June, decreasing to 22% greater in September, and similar for the two locations by the end of the growing season. Caliper was not affected by production light level at any data collection, except August when there was an interaction between location and light.

Similar to ‘Natchez’ and ‘Tuscarora’, ‘Muskogee’ was generally taller in Oregon in the second season. All plants in Alabama and 73% of plants in Oregon had or were flowering by the end of the season. Plants previously grown under shade were 13% taller in June than plants grown in full sun at both locations and similar thereafter (Table 5). Caliper of plants in Alabama was 42% greater in June than that of plants in Oregon, with an interaction between location and previous production light level in August and October. Plants grown in Alabama in full sun had 60% and 29% greater caliper in August and October, respectively, than that of plants in Oregon. Similarly, caliper was greater for plants previously grown under shade in Alabama in August, but similar by the end of the growing season. In Alabama, there was no difference in caliper between light regimes in August but caliper of plants in full sun was 13% greater in October. Plants previously grown under shade in Oregon had 16% more caliper than plants in full sun in August, but were similar thereafter.

There was no growth or flowering effect on any cultivar tested due to topdressed fertilizer. Speculation is the 12-month release fertilizer used in this experiment released at a rate too low to produce measurable results.

Differences in meteorological factors such as higher maximum and minimum temperatures in Alabama appeared to have a direct effect on the plants in this experiment. Average daily maximum temperatures in Alabama ranged from 3.4 to 5.7C (6.3 to 10.2F) higher than in Oregon, while minimum daily temperatures were 5.3 to 7.3C (9.3 to 13.2F) lower in Oregon than in Alabama (Table 1). There was a similar range of temperatures in 2005. The higher minimum and maximum temperatures in Alabama may explain the early growth differences. Rainfall from April to October in 2004 and 2005 totaled 719 mm (28.3 in) and 904 mm (35.6 in), respectively, for Alabama while rainfall in Oregon for 2004 and 2005 totaled 11.2 mm (0.44 in) and 14.5 mm (0.57 in), respectively.

Oregon's Willamette River Valley receives 100 to 125 cm (40 to 50 in) of precipitation each year, however, most occurs during the dormant season (November through March). This region of Oregon is largely considered to have arid Mediterranean-like summers.

Nursery operators in the southeastern U. S. contend with summer temperatures which regularly exceed 32C (90F), high relative humidities, and frequent afternoon thundershowers (15). Crapemyrtles prefer hot, sunny climates where flowering is profuse and, thus, are ideally suited for southern and southwestern regions of the U.S. (USDA Cold Hardiness Zones 7-9). Western regions of Oregon and Washington are in USDA Zones 7 and 8; however, crapemyrtles are rarely planted in landscapes and flower sporadically, if at all. Oregon's summers are milder than those of Alabama with lower night temperatures. The consensus is although these environments have good sunlight, moderate winters, and adequate moisture, they lack the hot weather found in the South where flowering is prolific (2). Guidry (1977) reported that high temperatures favor rapid floral bud initiation and development in dwarf crapemyrtles. This may be true considering that no crapemyrtle flowered in Oregon in 2004. However, in 2005 there was a considerable increase in flowering. All 'Natchez' in Oregon flowered along with 50%, 66%, and 66%, of Dynamite™, 'Muskogee', and 'Tuscarora', respectively. Lower temperatures in Oregon, especially the differences in minimum temperature, may have contributed to the decreased flowering. Cold tolerance of plants in Oregon became an issue as temperatures started to drop towards the end of the growing season. While flowering essentially shuts down vegetative growth in crapemyrtle, the lack of flowering which may have led to increased height growth of plants in Oregon in 2004 also resulted in plants still actively growing until exposed to several hard freezes, which injured shoot tips. All plants survived with no visible effects on vigor in 2005. In 2005, plants in Oregon that flowered ceased shoot growth before exposure to freezing temperatures and were not injured, as opposed to those that did not flower.

Height growth of plants generally was greater when grown under shade in Alabama, while caliper was greater in full sun with two of the four cultivars. Through the use of lower production light levels it was possible to accelerate height growth in Alabama of ‘Muskogee’, ‘Natchez’, and ‘Tuscarora’. ‘Muskogee’ was the only cultivar to respond with increased height to lower production light levels in Oregon; however caliper of all cultivars was similar under the two production light levels. By growing all plants in full sun the second year it was possible to regain caliper lost due to growth under shade the previous year, although some of the height advantage gained from growing under shade decreased. However, plants developed sufficient clear trunk height the first season so that head development rather than additional height would be more important thereafter. Results of this study suggest growing plants in Oregon or similar USDA zones in the region can accelerate the development of tree-form crapemyrtle, compared to production in Alabama. All cultivars were taller in Oregon, although caliper was greater in Alabama. The suppression or lack of flowering in Oregon can lead to increased growth throughout the growing season resulting in the necessary structure for further development into tree-form crapemyrtles.

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Table 1. Effect of geographic location and production light level on two container-grown crapemyrtle cultivars, 2004[z].

		Dynamite™									
Location	Light level	Height (cm)					Caliper (mm)				
		June	July	Aug.	Sept.	Oct.	June	July	Aug.	Sept.	Oct.
AL	Sun	62.8	91.4	82.7	86.8	86.6	7.6	9.3	10.0	10.9	10.6
	50% shade	66.8	91.1	87.9	97.5	95.8	6.4	7.9	9.0	9.1	9.3
OR	Sun	23.5	64.8	107.3	124.9	128.6	2.6	5.3	7.1	8.7	9.7
	50% shade	24.1	66.0	115.1	127.8	130.2	2.6	4.9	7.2	8.7	9.2
	Main effects[y]										
	Loc	***	***	***	***	***	***	***	***	***	*
	Light	NS	NS	NS	NS	NS	**	***	NS	***	***
	Loc x Light	NS	NS	NS	NS	NS	**	*	*	***	*
	AL v. OR FS[x]	-	-	-	-	-	***	***	***	***	**
	AL v. OR SH	-	-	-	-	-	***	***	***	NS	NS
	FS v. SH AL	-	-	-	-	-	***	***	**	***	***
	FS v. SH OR	-	-	-	-	-	NS	NS	NS	NS	NS

		'Tuscarora'									
		June	July	Aug.	Sept.	Oct.	June	July	Aug.	Sept.	Oct.
AL	Sun	65.7	80.2	72.3	72.7	70.5	10.5	11.1	11.7	12.1	12.1
	50% shade	84.2	109.6	100.4	110.1	110.2	9.6	10.9	11.9	12.2	12.2
OR	Sun	30.6	72.1	123.8	158.1	170.9	3.4	6.2	8.7	10.9	12.1
	50% shade	33.2	73.3	131.8	163.8	176.2	3.0	6.1	8.8	10.6	11.8
	Main effects										
	Loc	***	***	***	***	***	***	***	***	***	NS
	Light	***	***	**	***	***	**	NS	NS	NS	NS
	Loc x Light	**	***	*	**	**	NS	NS	NS	NS	NS
	AL v. OR FS	***	NS	***	***	***	-	-	-	-	-
	AL v. OR Sh.	***	***	***	***	***	-	-	-	-	-
	FS v. SH AL	***	***	***	***	***	-	-	-	-	-
	FS v. SH OR	NS	NS	NS	NS	NS	-	-	-	-	-

[z]The experiment was conducted simultaneously in Auburn, AL and Aurora, OR.
[y]NS, *, **, and *** represent non-significant, and significant effects where $P \leq 0.05$, 0.01, and 0.001, respectively.
[z]FS = full sun, SH = 50% shade.

Table 2. Mean monthly maximum (T_{max}) and minimum (T_{min}) temperatures and monthly rainfall for Auburn, AL and Aurora, OR, respectively during Summer 2004 and 2005[z].

	2004					
	Alabama			Oregon		
Month	T_{max} (C)	T_{min} (C)	Rain (mm)	T_{max} (C)	T_{min} (C)	Rain (mm)
April	23.6	10.9	71.4	19.2	5.8	0.9
May	28.9	17.8	94.2	19.4	9.3	1.6
June	30.2	21.0	84.6	24.1	11.9	1.4
July	32.4	22.1	87.4	28.9	13.9	0.1
August	30.6	20.8	131.3	28.4	14.8	2.1
September	27.9	19.3	197.1	21.8	11.0	1.5
October	25.6	16.2	52.6	17.9	8.2	3.6
	2005					
April	22.9	10.5	120.1	15.5	5.9	2.5
May	26.7	14.9	62.0	20.0	10.5	4.1
June	29.9	20.9	199.9	21.0	10.8	2.3
July	31.5	22.7	186.7	27.8	13.3	0.5
August	31.3	22.6	183.6	29.0	12.5	0.2
September	31.2	20.7	45.5	23.6	8.7	1.9
October	24.5	13.2	106.2	16.7	8.8	3.1

[z]Data from weather stations at Auburn, AL and Aurora, OR.

Table 3. Effect of geographic location and production light level on two container-grown crapemyrtle cultivars, 2004^{z}.

Location	Light level	Height (cm) June	July	Aug.	Sept.	Oct.	Caliper (mm) June	July	Aug.	Sept.	Oct.
'Natchez'											
AL	Sun	83.5	124.3	111.8	133.4	156.2	10.4	12.6	13.8	14.2	14.5
	50% shade	84.6	138.7	159.7	185.3	201.7	8.2	10.1	12.4	12.6	12.5
OR	Sun	34.3	93.3	174.2	222.0	247.4	3.7	6.6	9.3	11.5	13.0
	50% shade	37.9	92.6	175.2	228.8	265.7	4.0	6.7	9.2	10.8	12.2
	Main effects[y]										
	Loc	***	***	***	***	***	***	**	***	***	*
	Light	NS	NS	***	**	**	**	**	**	***	**
	Loc x Light	NS	NS	***	**	NS	***	***	*	NS	NS
	AL v. OR FS[x]	-	-	***	***	-	***	***	***	-	-
	AL v. OR SH	-	-	NS	***	-	***	***	***	-	-
	FS v. SH AL	-	-	***	***	-	***	***	***	-	-
	FS v. SH OR	-	-	NS	NS	-	NS	NS	NS	-	-
'Muskogee'		June	July	Aug.	Sept.	Oct.	June	July	Aug.	Sept.	Oct.
AL	Sun	91.3	127.3	122.7	120.9	124.1	10.7	12.8	14.8	14.7	14.7
	50% shade	109.0	161.8	153.3	196.6	184.5	9.8	11.4	12.9	14.2	14.7
OR	Sun	40.6	95.4	165.4	200.8	217.0	3.9	7.3	9.7	12.0	13.2
	50% shade	41.7	103.2	187.0	229.9	248.9	4.0	7.4	9.9	11.7	13.5
	Main effects										
	Loc	***	***	***	***	***	***	***	***	***	NS
	Light	NS	**	**	***	***	NS	NS	*	NS	NS
	Loc x Light	NS	NS	NS	*	NS	NS	NS	*	NS	NS
	AL v. OR FS	-	-	-	***	-	-	-	***	-	-
	AL v. OR SH	-	-	-	**	-	-	-	***	-	-
	FS v. SH AL	-	-	-	***	-	-	-	***	-	-
	FS v. SH OR	-	-	-	**	-	-	-	NS	-	-

[z] The experiment was conducted simultaneously in Auburn, AL and Aurora, OR.

[y]NS, *, **, and *** represent non-significant, and significant effects where $P \leq 0.05$, 0.01, and 0.001, respectively.

[x]FS = full sun, SH = 50% shade.

Table 4. Effect of geographic location and production light level on two container-grown crapemyrtle cultivars[z], 2005.

		Dynamite™						'Tuscarora'					
		Height (cm)			Caliper (mm)			Height (cm)			Caliper (mm)		
Location	Light Level	June	Aug.	Oct.	June	Aug.	Oct.	June	Aug.	Oct.	June	Aug.	Oct.
AL	Sun	115.3	163.3	168.0	11.2	15.0	17.4	109.5	184.2	186.0	12.8	18.0	19.6
	50% shade	123.9	157.3	160.5	11.0	15.9	18.0	139.1	195.9	205.5	13.6	18.9	21.2
OR	Sun	135.4	170.7	273.1	8.5	10.2	11.5	162.6	200.7	230.3	11.4	12.1	14.3
	50% shade	132.9	167.4	200.4	9.3	10.5	12.7	166.4	184.1	231.7	11.2	12.9	15.7
	Main effects[y]												
	Loc	NS	NS	**	***	***	***	***	NS	*	**	***	***
	Light	NS	NS	NS	NS	NS	NS	**	NS	NS	NS	*	*
	Loc x Light	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
	AL v. OR FS[x]	-	-	-	-	-	-	-	-	-	-	-	-
	AL v. OR SH	-	-	-	-	-	-	-	-	-	-	-	-
	FS v. SH AL	-	-	-	-	-	-	-	-	-	-	-	-
	FS v. SH OR	-	-	-	-	-	-	-	-	-	-	-	-

[z]All plants grown in full sun for the second season. The experiment was conducted simultaneously in Auburn, AL and Aurora, OR.

[y]NS, *, **, and *** represent non-significant, and significant effects where $P \leq 0.05$, 0.01, and 0.001, respectively.

[x]FS = full sun, SH = 50% shade.

Table 5. Effect of geographic location and production light level on two container-grown crapemyrtle cultivars[z], experiment 1, 2005.

		'Natchez'						'Muskogee'					
		Height (cm)			Caliper (mm)			Height (cm)			Caliper (mm)		
Location	Light Level	June	Aug.	Oct.	June	Aug.	Oct.	June	Aug.	Oct.	June	Aug.	Oct.
AL	Sun	195.2	209.5	222.5	16.1	19.6	21.4	178.0	230.7	243.5	16.7	23.2	25.7
	50% shade	226.8	250.0	236.1	15.2	19.7	21.9	222.8	260.6	265.0	19.9	21.7	22.8
OR	Sun	231.5	268.1	282.7	10.9	13.6	17.3	225.4	259.4	283.0	12.5	14.5	19.9
	50% shade	240.2	286.5	305.9	13.1	15.6	19.4	231.1	273.7	298.7	13.3	16.8	20.9
	Main effects[y]												
	Loc	*	***	***	***	***	***	*	NS	**	***	***	***
	Light	NS	**	NS	*	*	NS	*	*	NS	NS	NS	NS
	Loc x Light	NS	NS	NS	**	*	NS	NS	NS	NS	NS	*	*
	AL v. OR FS[x]	-	-	-	***	***	-	-	-	-	-	***	***
	AL v. OR SH	-	-	-	**	***	-	-	-	-	-	***	NS
	FS v. SH AL	-	-	-	NS	NS	-	-	-	-	-	NS	**
	FS v. SH OR	-	-	-	**	*	-	-	-	-	-	*	NS

[z]All plants grown in full sun for the second season. The experiment was conducted simultaneously in Auburn, AL and Aurora, OR.
[y]NS, *, **, and *** represent non-significant, and significant effects where $P \leq 0.05$, 0.01, and 0.001, respectively.
[x]FS = full sun, SH = 50% shade.

CHAPTER IV

Growth Response of Crapemyrtle to Coppicing

Abstract

The effects of production light level on coppicing and coppice timing were evaluated as means of accelerating the development of tree-form crapemyrtles. By the end of the growing season, 'Fantasy' and 'Tuscarora' coppiced in March and grown under 80% shade were 23% and 18% taller, respectively, than coppiced plants in full sun, but similar in height to plants under 50% shade. Coppiced Dynamite™ under 80% shade were 11% and 15% taller than coppiced plants in full sun and under 47% shade, respectively, by the end of the growing season. Height of 'Fantasy' and 'Tuscarora', but not 'Natchez', at the end of the growing season decreased as coppicing was delayed from January to June. 'Natchez' coppiced in March were taller than plants coppiced in January and February and 68% taller than plants coppiced in June by the end of the growing season. Stem area of coppiced Dynamite™ and 'Fantasy' grown in full sun was greater than plants under 47% shade and similar to that of plants under 80% shade. Coppiced 'Tuscarora' under 47% shade had more stem area than plants under 80% shade, but similar to coppiced plants in full sun. Stem area of coppiced 'Carolina Beauty' was greatest in full sun, followed by that of plants under 50% shade, and least in plants grown under 80% shade. Stem area of 'Fantasy', 'Natchez', and 'Tuscarora', decreased linearly as coppicing was

delayed. Visually, coppiced plants had more uniform shoot diameters and less branching than non-coppiced plants.

Index words: container production, coppice, production light level.

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

Significance to the Nursery Industry

Most cultivars of crapemyrtle grow vigorously under nursery conditions; however, some cultivars begin flowering by early summer, resulting in suppression of vegetative growth, particularly height growth. Coppicing, cutting trees to the ground to encourage vigorous growth, resulted in plants with visually straighter and less branched shoots which were more uniform in caliper than non-coppiced plants. Coppiced plants had the necessary structure for further development into high quality tree-form crapemyrtles that the non-coppiced plants lacked. Height growth of coppiced plants generally was greater when grown under shade, while stem area, an indicator of caliper growth, was greater when plants were grown in full sun. Coppicing crapemyrtle while dormant resulted in greater height and stem area than delaying until the growing season, with no effect on survival. Coppicing may provide growers a means of accelerating growth and improving quality of tree-form crapemyrtles.

Introduction

Crapemyrtles are valuable landscape species grown in the South, Southwest, and West Coast as shrubs or small trees and are recognized for their exceptional seasonal ornamental characteristics. Lengthy summer flowering and diversity of flower colors, plant sizes and growth habits are appreciated by American horticulturalist and gardeners (3). Container and field grown crapemyrtles are major crops in the nursery industry. Breeding programs over the last 30 years have produced superior forms with a wide range of plant sizes and habits, improved flowering, new flower colors, ornamental bark, ornamental foliage, disease resistance and increased vigor (9). Deciduous flowering trees, which include crapemyrtle, accounted for $276 million or 7% of the total gross sales for U. S. nursery production in 2003 (21). Most cultivars of crapemyrtle are vigorous growers under nursery conditions; however, some cultivars begin flowering by early summer (2). This early flowering can result 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 a standard form of crapemyrtle with a central leader and 112 cm (4 ft) to 183 cm (6 ft) of clear trunk, pruning exacerbates the problem by stimulating new shoot formation, often from the main trunk.

Coppicing, cutting trees to the ground to encourage vigorous regrowth, often results in straight trunks with little lateral branching. Sprouts may grow more rapidly in height and biomass than shoots of intact plants, although the causes of this growth stimulation are not known (11). Hypotheses regarding the nature of this rapid regrowth often focus on the abundant resources afforded to sprouts by a relatively large root system (16, 19). Increased leaf photosynthetic productivity of coppiced red oak (*Quercus rubra*) helped offset the loss of plant mass and internal resources resulting from coppicing (11). Coppicing of young Chinese pistache (*Pistacia chinensis*) increased the number of marketable trees with straight trunks (12), a highly desirable response in tree-form crapemyrtle production, although time of coppicing may lead to survival issues. Chinese pistache coppiced in November had higher survival rates than trees coppiced in December or January (12). It is generally stated that coppicing is maximized, in terms of biomass production, by cutting during the dormant season and minimized by cutting during active growth (8, 18). Coppicing of red oak while actively growing led to substantial differences in net relative growth compared to dormant coppicing, due to alterations in leaf gas exchange largely through coppice-induced changes in leaf-root balance (11). The effects of coppicing actively growing crapemyrtle on survival are not known. While practiced in shade tree nurseries in the Northwest and other regions of the U.S. on other species, coppicing is not typically used in the production of tree-form crapemyrtles.

There are three major mechanisms that can control the development of tree form: apical dominance, which can affect both the patterns and orientation of axes development; allocation mechanisms that maintain feedbacks between leaf and wood production for both transport capacity and mechanical support; and shading that reduces light intensity (22). Apical dominance is the control exerted by the apical portions of the shoot over the outgrowth of lateral buds (4). The influence of light on apical dominance can be dramatic; the higher the light intensity the weaker the apical dominance (1, 10) Shading reduces photosynthesis and eventually reduces 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 (22). Leaf shading enriches the far-red component of the transmitted light and causes a reduction of the fluence rate (irradiance) and light quality (5). Far-red light inhibits the initiation of bud outgrowth and also enhances subsequent bud elongation after it has been initiated (15, 20). Enhanced upward growth is desirable in the production of tree-form crapemyrtles.

An experiment was conducted beginning in the spring of 2004 to study the effect of production light level on vegetative growth of several coppiced crapemyrtle cultivars. Coppicing combined with lower production light levels may suppress flowering and promote more height growth in a single season than coppicing of trees in full sun. A second experiment in 2005 determined how coppicing time affected survival and growth of crapemyrtle during nursery production.

Materials and Methods

Experiment 1. Four cultivars of crapemyrtle were used to determine how three light regimes affect vegetative growth following coppicing [*Lagerstroemia indica* 'Carolina Beauty' and 'Whitt II' (Dynamite™), *Lagerstroemia fauriei* 'Fantasy', and *Lagerstroemia indica ×fauriei* 'Tuscarora']. In January 2004, 40 plants of each cultivar in 11.4 L (#3) containers were selected from local nursery stock for uniformity visually based on an average height of 105 cm (3.5 ft) and caliper of 2.5 cm (1 in). Plants were repotted on February 26, 2004, into 38 L (#10) containers, containing an 8:1 (by vol) pinebark:sand substrate 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. All plants were spaced pot-to-pot in full sun under overhead irrigation until the initiation of treatments. On March 11, 2003, before bud break, 30 plants of each cultivar were coppiced at 6.4 cm (2.5 in) above the substrate surface and 10 plants of each cultivar were placed under full sun, 50% shade, or 80% shade. 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 full sun. Treatments included a standard (single trunk) uncut control placed in full sun in addition to coppiced plants under the 3 light regimes.

Three dominant shoots were selected on each of the coppiced plants on June 16, 2004, and all other shoots removed. The three shoots were tied together with plastic tape to encourage upright growth. Plants were trained throughout the growing season into tree-form by weekly removal of lateral shoots from the main shoots. Height from the substrate surface to the three shoot tips were measured monthly and averaged, beginning in July and continuing until October 2004. Caliper was measured on all shoots monthly at a 2.5 cm (1 in) height using a digital caliper. Because coppiced plants formed three smaller-diameter shoots and non-coppiced controls typically had a single larger-diameter shoot, caliper growth was compared by first calculating the sum of the cross-sectional areas of all shoots of a plant at 2.5 cm (1 in) height. The presence of flowers was also noted at each data collection. Treatments were replicated with 10 single plants and cultivars were separated. Data were subjected to analysis of variance using SAS statistical software package (16) and means were separated using the Waller-Duncan test ($\alpha = 0.05$).

Experiment 2. To determine how time of coppicing affects vegetative growth and flowering of crapemyrtle during nursery production, 'Natchez', 'Tuscarora', and 'Fantasy' were used. Uniform plants of each cultivar were visually selected based on height and caliper from local nursery stock. 'Tuscarora' were repotted from 11.4 L (#3) to 26.5 L (#7) pots and 3.8 L (#1) 'Natchez' and 'Fantasy' were repotted into 11.4 L (#3) pots on January 24, 2005, using the same substrate as in experiment 1 and placed in full sun under overhead irrigation. Treatments included coppicing 10 plants of each cultivar 2.5 cm (1 in) above the substrate surface monthly starting in January and continuing until June. An uncut control treatment replicated with ten plants per cultivar was also included. All plants were in full sun and irrigated daily. Plants were completely randomized within cultivar and spaced pot-to-pot to encourage upright, non-branched shoots. Self-shading associated with close planting suppresses lateral bud outgrowth and branching (13). On June 24, 2005, three dominant shoots were selected on each plant in each of the coppicing treatments and the remaining shoots were removed to encourage a tree-form growth habit. Height of each plant was recorded monthly from August to October 2005, by measuring from the substrate surface to the tips of the three shoots selected, then averaged. Caliper was recorded 2.5 cm (1 in) from the base of each shoot. Caliper growth was compared by calculating the sum of the cross-sectional areas of all shoots of a plant. Flowering of each plant was rated at each sampling using a four part scale in which 1 = no visible floral development, 2 = visible floral development but no color, 3 = floral color, and 4 = post floral color. Data were subjected to analysis of variance using SAS statistical software package. Response to timing was determined using single-degree-of-freedom orthogonal contrasts.

Results and Discussion

Experiment 1. The response of coppiced plants to production light levels varied with cultivar and data collection date. Coppicing of 'Carolina Beauty' produced plants of similar height in full sun and 50% shade in July and August, whereas coppiced plants in 80% shade were similar in height to plants under 50% shade. Height of 'Carolina Beauty' grown in full sun was 24% greater than height of plants under 80% shade in July (Table 1). Coppiced plants grown under 50% shade were taller than coppiced plants in full sun and 80% shade in September and October. Height of Dynamite™ and 'Tuscarora' was not affected by production light levels until the end of the growing season when Dynamite™ under 80% shade were 11% and 15% taller than plants in full sun and under 50% shade, respectively. 'Tuscarora' under 80% shade were 18% taller than those in full sun but similar in height to plants under 50% shade. Height of 'Fantasy' was not affected by light levels in July, but greater under 50% and 80% shade thereafter, with plants grown under 80% shade 23% taller than coppiced plants in full sun in October. Increased height growth under shade is probably due to the greater far-red light, which enhances bud elongation (5, 15, 20). Height growth of all cultivars may have been reduced by the flowering of terminal shoots which results in a reduction of vegetative growth (7, 14). In August, when increased height of 'Fantasy' in the shade treatments was first evident, 60% of plants in full sun and 10% of plants under 80% shade were in flower, while no plants under 50% shade were in flower (Table 2). At the end of the growing season, 70% of coppiced 'Fantasy' in full sun had flowered, while only 10% of plants each shade level had flowered. Flowering appeared to be reduced or delayed by shade, especially 80% shade, in all cultivars tested.

Stem area of coppiced Dynamite™ and ‘Fantasy’ responded similarly to production light levels with plants in full sun having more area than plants under 50% or 80% shade. By the end of the growing season, Dynamite™ grown under both shade levels had similar stem areas, but 45% less stem area than that of coppiced plants in full sun (Table 1). There was no difference in stem area between ‘Fantasy’ grown under 50% and 80% shade at any data collection. By the end of the growing season, coppiced ‘Fantasy’ in full sun had 61% more stem area than plants under 50% shade which were similar in stem area to plants under 80% shade. Stem area of coppiced ‘Carolina Beauty’ was greatest for plants in full sun, followed by those grown under 50% shade, and least in plants grown under 80% shade. Differences were most pronounced in July when coppiced plants in full sun had 254% more stem area than plants in 80% shade, and least in October when the difference had decreased to 166%. Coppiced ‘Tuscarora’ in full sun was similar in stem area to coppiced plants grown under 50% shade, but 70% greater than plants in 80% shade in October.

Height and stem area of non-coppiced plants of all cultivars except ‘Fantasy’ was greater than those of coppiced plants at all data collection dates. Coppiced ‘Fantasy’ grown under 80% shade were 22% and 17% taller than non-coppiced controls in full sun in September and October, respectively, and coppiced plants in full sun had 50% more stem area than non-coppiced controls in October. This may be due in part to the abundance of resources afforded to sprouts by a relatively large root system (16, 19) and also due to a faster growth rate of *L. fauriei* compared to *L. indica* (6). While height and stem area indicate more shoot biomass of non-coppiced plants, there were visual differences supporting coppicing. All coppiced plants, regardless of the production light level, appeared to have straighter and less branched shoots which were more uniform in caliper than non-coppiced plants (Figure 1). Non-coppiced plants typically had a single shoot from the substrate surface, extensive branching, and shoots of widely varying lengths and calipers. Coppiced plants had the necessary structure and framework for further development into high quality tree-form crapemyrtles that the non-coppiced plants lacked. Coppicing has been shown to increase the number of marketable trees with other species (12), and may be practical in obtaining tree-form crapemyrtle.

Experiment 2. Height of 'Fantasy' and 'Tuscarora' decreased linearly as coppicing was delayed from January to June. By the end of the growing season, 'Fantasy' and 'Tuscarora' coppiced in January were 72% and 43% taller, respectively, than plants coppiced in June (Table 3). 'Natchez' responded to coppicing quadratically at all sampling dates with plants coppiced in March being 5% and 3% taller than plants coppiced in January and February, respectively, at the end of the season, followed by a rapid drop in height as coppicing was delayed. Plants coppiced in June were 41% shorter than those coppiced in March when measured in October. This agrees with previous research showing an increased relative growth rate and increased final height of plants coppiced while dormant opposed to coppiced while actively growing (11). All cultivars showed a linear decrease in stem area as coppicing was delayed from January to June. 'Natchez' and 'Tuscarora' coppiced in January had 225% and 78%, respectively, more stem area than plants coppiced in June at the end of the growing season. 'Fantasy' coppiced in January produced plants with 120% more stem area than plants coppiced in

June. Red oak coppiced while actively growing led to substantially less net relative growth than dormant coppicing (11). This may be true in crapemyrtles due to the general decrease in height and stem area with delayed coppicing. It has been shown that the time of coppicing of some species is important for survival (12). Across all coppicing treatments for each cultivar (n=60), 'Natchez' and 'Tuscarora' had 10% mortality while 'Fantasy' had 25% (data not shown). There was no effect of coppice timing on mortality rates with any cultivar.

Floral rating varied among cultivars in response to coppice timing. As coppicing was delayed there was a linear decrease in floral rating of 'Tuscarora' and 'Natchez' (Table 4). 'Tuscarora' in each treatment had floral development or floral color visible [Floral rating (FR) $\geq$ 2] by the end of the growing season, whereas, 'Natchez' coppiced in April, May, and June never reached a point of visible floral development (Table 4). In August, 'Natchez' coppiced in January or February were showing color or at post color (FR $\geq$ 3) while there was no visible floral development (FR = 1) in plants coppiced in April, May, or June. In September, all 'Natchez' coppiced in January, February, or March were at post color (FR = 4), with no change in plants coppiced in April, May, or June. Essentially there was no flowering of 'Natchez' with plants coppiced after March. There was no visible floral development (FR = 1) in 'Fantasy' regardless of treatment (data not shown).

By the end of the growing season, 'Natchez' coppiced in March was 26% taller than the non-coppiced plants but with similar stem area. 'Tuscarora' coppiced in January or February was similar in height to the non-coppiced controls at all data collection dates, while 'Fantasy' coppiced in January was similar in height to the control. Non-coppiced

‘Tuscarora’ had greater stem area at all data collection dates than coppiced plants, regardless of coppiced date. Stem area of non-coppiced ‘Tuscarora’ was 68% and 198% greater than that of plants coppiced in January and June, respectively, at the end of the season. Stem area of ‘Fantasy’ coppiced in January, February, or March were similar to non-coppiced controls by the end of the season. Coppiced plants of all three cultivars showed tremendous growth for one growing season compared to the non-coppiced controls. This was also true in a 1993 study where sprouts of coppiced red oak were 30% shorter than non-coppiced controls at final harvest, although the height difference from the beginning of the season to the end was nearly double that of controls (11).

While height of ‘Fantasy’ and ‘Tuscarora’, but not ‘Natchez’, and stem area of ‘Natchez’ and ‘Tuscarora’ suggest superior growth of non-coppiced plants, there were the same visual differences, as noted in experiment 1, supporting coppicing. Coppiced plants appeared to have much straighter and less branched shoots that were more uniform in each treatment (Figure 1). Non-coppiced plants typically had extensive branching from the base of the plant up, and a wide variety and caliper of the shoots, not conducive to tree-form crapemyrtle production.

Results of this study suggest coppicing can be beneficial to the development of high quality tree-form crapemyrtles. Height growth of coppiced plants generally was greater when grown under shade, while stem area was greater when plants were grown in full sun. Through the use of lower production light level and coppicing it was possible to accelerate height growth of ‘Dynamite’, ‘Fantasy’ and ‘Tuscarora’. Coppicing crapemyrtle while dormant resulted in greater height and stem area than delaying until the growing season, with no effect on survival. The results of the second experiment suggest that coppicing before March rather than delaying, would lead to increased growth throughout the growing season as evident with ‘Fantasy’, ‘Natchez’ and ‘Tuscarora’. Coppicing resulted in plants with visually straighter and less branched shoots which were more uniform in caliper than non-coppiced plants. Coppiced plants had the necessary structure for further development into high quality tree-form crapemyrtles that the non-coppiced plants lacked. Coppicing may provide growers a means of accelerating the growth and improving the quality of tree-form crapemyrtles.

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Table 1. Effects of coppicing and production light level on four container-grown crapemyrtle cultivars in Auburn, AL, experiment 1, 2004.

Coppiced	Production light level	Height (cm) July	Aug.	Sep.	Oct.	Stem area (mm²)[z] July	Aug.	Sep.	Oct.
		'Carolina Beauty'							
	Full sun	198.8a[y]	188.0a	214.0a	207.0a	420.0a	473.1a	499.9a	496.7a
+[x]	Full sun	128.6b	123.8b	118.0c	113.3c	263.1b	368.6b	370.0b	387.4b
+	50% shade	124.1bc	140.3b	141.5b	143.2b	150.0c	199.0c	249.8c	274.0c
+	80% shade	103.6c	122.7b	103.3c	118.4c	74.3d	109.9d	141.1d	145.2d
		Dynamite™							
		July	Aug.	Sep.	Oct.	July	Aug.	Sep.	Oct.
	Full sun	181.6a	181.0a	181.2a	180.4a	434.4a	488.5a	504.0a	476.6a
+	Full sun	120.3b	119.4b	112.6b	111.9c	351.8b	483.7a	412.4a	378.2b
+	50% shade	113.6b	121.2b	110.0b	107.8c	152.2c	194.4b	184.9b	209.4c
+	80% shade	119.0b	124.3b	116.6b	123.8b	115.7c	133.2b	147.5b	158.4c
		'Fantasy'							
		July	Aug.	Sep.	Oct.	July	Aug.	Sep.	Oct.
	Full sun	191.0a	207.5ab	195.3bc	205.7bc	476.4a	671.8a	750.9b	779.7b
+	Full sun	144.0b	183.1b	185.4c	195.9c	384.7b	754.9a	965.9a	1147.5a
+	50% shade	158.8b	216.1a	224.5ab	224.8ab	230.4c	489.8b	636.8bc	710.6b
+	80% shade	148.1b	220.9a	237.6a	241.5a	200.2c	434.5b	565.8c	628.8b
		'Tuscarora'							
		July	Aug.	Sep.	Oct.	July	Aug.	Sep.	Oct.
	Full sun	232.2a	231.9a	205.8a	222.1a	604.4a	789.7a	776.6a	767.4a
+	Full sun	136.9b	143.3b	130.8b	132.9c	374.4b	505.9b	519.9b	554.4b
+	50% shade	146.3b	145.4b	137.0b	144.1cb	230.9c	337.4c	395.4bc	432.5bc
+	80% shade	153.4b	155.9b	154.5b	157.3b	180.1c	255.6c	312.7c	326.3c

[z] Sum of the cross-sectional area of all shoots per plant measured at 2.5 cm (1 in) above the substrate surface.
[y] Mean separation within cultivar and date by the Waller-Duncan test, $\alpha = 0.05$.
[x] Coppiced.

Table 2. Effects of coppicing and production light level on flowering of four container-grown crapemyrtle cultivars in Auburn, AL, experiment 1, 2004.

Coppiced	Production light level	% Flowering[z] 'Carolina Beauty'			% Flowering[z] Dynamite™		
		July	Aug.	Sep.	July	Aug.	Sep.
	Full sun	70	100	100	90	100	100
+[y]	Full sun	20	80	80	0	60	70
+	50% shade	0	80	80	0	30	30
+	80% shade	0	50	60	0	0	0

Coppiced	Production light level	'Fantasy'			'Tuscarora'		
		July	Aug.	Sep.	July	Aug.	Sep.
	Full sun	10	100	100	100	100	100
+	Full sun	0	60	70	40	80	100
+	50% shade	0	0	10	20	100	100
+	80% shade	0	10	10	10	90	90

[z]n=10.
[y]Coppiced.

Table 3. Effect of time of coppicing on height and stem area of three container-grown crapemyrtle cultivars in Auburn, AL, experiment 2, 2005.

Coppiced	Timing	Height (cm) Aug.		Sept.		Oct.		Stem area (mm^2)[z] Aug.		Sept.		Oct.	
		'Fantasy'											
-		211.6		207.3		218.5		377.1		375.6		407.4	
+	Jan.	192.0		194.7		202.0		299.9		385.6		397.5	
+	Feb.	177.3		172.6	*	177.7	*	346.6		397.2		425.9	
+	Mar.	183.0	*[y]	175.4	*	186.9	*	269.7	*	326.7		326.7	
+	Apr.	125.4	*	145.4	*	142.9	*	162.5	*	196.9	*	222.1	*
+	May	97.1	*	128.5	*	119.4	*	138.7	*	177.9	*	207.6	*
+	Jun.	98.6	*	116.9	*	117.3	*	95.2	*	155.0	*	180.6	*
Significance[x]		L***		L***		L***		L***		L***		L***	
		'Natchez'											
-		160.5		178.8		188.4		389.9		421.5		414.5	
+	Jan.	212.1	*	216.9	*	225.8	*	316.7		320.5	*	348.7	
+	Feb.	229.6	*	229.2	*	232.0	*	315.7		320.0	*	368.0	
+	Mar.	215.4	*	232.4	*	236.8	*	307.3		353.3	*	385.5	
+	Apr.	184.7		193.6		191.7		116.6	*	157.6	*	162.7	*
+	May	170.0		180.6		173.0		86.7	*	114.6	*	143.8	*
+	Jun.	119.5	*	125.4	*	140.5	*	46.6	*	80.9	*	107.2	*
Significance		Q***		Q***		Q***		L***		L***		L***	
		'Tuscarora'											
-		179.7		181.6		191.0		639.6		679.2		713.8	
+	Jan.	163.9		163.0		164.9		399.9	*	390.7	*	425.0	*
+	Feb.	175.5		165.5		164.6		381.4	*	378.4	*	421.7	*
+	Mar.	152.4	*	159.4		157.8	*	355.8	*	403.3	*	451.6	*
+	Apr.	134.0	*	142.4	*	140.7	*	299.3	*	317.7	*	382.9	*
+	May	114.4	*	123.3	*	123.6	*	221.3	*	265.3	*	307.7	*
+	Jun.	101.2	*	125.3	*	115.5	*	135.1	*	215.2	*	239.2	*
Significance		L***		L***		L***		L***		L***		L***	

[z]Sum of the cross-sectional area of all shoots per plant measured at 2.5 cm (1 in) above the substrate surface.
[y]Treatment means followed by an asterisks (*) significantly different from the non-coppiced control based on Dunnett's T-test, $\alpha = 0.05$.
[x]Significant linear (L) or quadratic (Q) ($P \leq 0.001$, ***) response based on single-degree-of-freedom orthogonal contrasts.

Table 4. Effect of time of coppicing on floral rating of two container-grown crapemyrtle cultivars in Auburn, AL, experiment 2, 2005.

		Floral rating[z]											
Coppiced	Timing	'Natchez'						'Tuscarora'					
		Aug.		Sept.		Oct.		Aug.		Sept.		Oct.	
		4.0		4.0		4.0		4.0		4.0		4.0	
+	Jan.	3.4		4.0		4.0		4.0		4.0		4.0	
+	Feb.	3.4		4.0		4.0		4.0		4.0		4.0	
+	Mar.	2.3	*[y]	4.0		4.0		3.8		3.9		4.0	
+	Apr.	1.0	*	1.0	*	1.0	*	3.6		3.7		4.0	
+	May	1.0	*	1.0	*	1.3	*	3.3	*	3.3		3.7	
+	Jun.	1.0	*	1.0	*	1.0	*	1.6	*	2.4	*	2.8	*
Significance[x]		L***		L***		L***		L***		L***		L**	

[z]Flower rating scale: 1 = no visible floral development, 2 = visible floral development but no flower color, 3 = flower color present, and 4 = post color.
[y]Treatment means followed by an asterisk (*) significantly different from the non-coppiced control based on Dunnett's T-test, α = 0.05.
[x]Significant linear (L) response at $P \leq 0.001$ (***) based on single-degree-of-freedom orthogonal contrast.

Figure 1. Non-coppiced vs. coppiced crapemyrtle grown in Auburn, AL.

CHAPTER V

Growth and Flowering of Crapemyrtle in Response to Tree Shelters

Abstract

Tree shelters were evaluated as a means of accelerating height growth of tree-form crapemyrtles. In the two experiments, Dynamite™ grown in shelters were 124% and 48% taller at the end of the growing season, while shelter-grown 'Potomac' were 61% and 50% taller. Height growth of 'Tuscarora' was not affected by tree shelters. Calipers of sheltered and non-sheltered 'Tuscarora' and Dynamite™ in the first experiment were similar at the end of the season, while caliper of 'Potomac' was 35% less when grown in shelters. In the second experiment, there were no caliper differences between sheltered and unsheltered Dynamite™ or 'Potomac' at the end of the growing season. All plants grown in tree shelters flowered later than unsheltered plants and appeared to have straighter, more upright trunks with minimal lateral shoot development.

Species used in this study: 'Tuscarora' crapemyrtle (*Lagerstroemia indica* L. ×*fauriei* Koehne), 'Potomac' and 'Whitt II' Dynamite™ crapemyrtle (*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 less 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 cm (4 ft) to 183 cm (6 ft) of clear trunk, pruning exacerbates the problem by stimulating new shoot formation, often from the main trunk. Our research shows that the use of tree shelters in the production of tree-form crapemyrtles can increase height growth and delay flowering while minimally affecting caliper growth, although all cultivars do not respond in the same way to the shelters. Tree shelters may provide growers with a low-input way to accelerate production of tree-form crapemyrtles.

Introduction

Crapemyrtles are valuable landscape species grown in the South, Southwest and along the West Coast as shrubs or small trees and are recognized for their excellent seasonal ornamental characteristics. Lengthy summer flowering and diversity of flower colors, plant sizes, and growth habits are appreciated in American landscapes (2). Crapemyrtles are an economically important nursery crop in both container and field production (13). Breeding programs over the last 30 years have produced superior forms with a wide range of plant sizes and habits, improved flowering, new flower colors, ornamental bark, ornamental foliage, disease resistance and increased vigor (7). Deciduous flowering trees, which include crapemyrtle, accounted for $276 million or 7%

of the total gross sales for United States nursery production in 2003 (13). Crapemyrtles are grown in many sizes from liners to large specimens and may be in production for several years before being marketed. Most cultivars of crapemyrtle are vigorous growers under nursery conditions; however, some cultivars begin flowering as early as May and continue into the fall (1, 7). This early flowering characteristic can result in less vegetative growth, particularly height growth. Height suppression is 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 cm (4 ft) to 183 cm (6 ft) of clear trunk, pruning exacerbates the problem by stimulating new shoot formation, often from the main trunk.

Previous research has shown that a single application of the plant growth regulator Pistill [(ethephon) Monterey Chemical, Fresno, CA] to open flowers resulted in as low as 2% fruit set and was an effective tool to induce flower abortion (3). Pistill applications also increased lateral branching but not plant height. A similar study demonstrated that multiple applications of Pistill to open flowers at 7-day intervals resulted in up to 96% flower abortion and greatly increased axillary shoot formation (9). These studies resulted in significant flower abortion and more lateral and internal branching, however overall plant height was not affected. Thus, these treatments are not applicable for the production of tree-form crapemyrtles.

Tree shelters, translucent tubes placed around tree seedlings, create a beneficial microclimate within the shelter of increased humidity and CO_2 levels and reduced drying and mechanical injury from wind (4). First available in the United States in 1989, tree shelters have accelerated the growth of some tree species (12, 15). Shelters typically increased survival and height growth, but effects differed among species (10). Increased temperature, humidity and CO_2 concentration within tree shelters have all been suggested as probable causes for the increased growth (12). The nature of the relationship between these environmental factors and their potential effect on plants grown in tree shelters is unclear.

Kjelgren et al. (2000), in studying water relations of container grown Kentucky coffee tree (*Gymnocladus dioica*) in translucent plastic shelters, reported increased air temperature, vapor pressure, and 70% less solar radiation, suggesting that trees respond to shelters as they do shade. Height increases of 60 to 600% from using tree shelters have been reported (12). Tree shelters tend to prolong the growing season for the seedling, giving it more degree-days in which to grow (8). Shelters can typically increase height growth but reduce the rate of trunk diameter growth which may result in trees without enough structural support to stand upright. Effects on diameter growth are species specific and can be positive or negative (10). West et al. (2002) reported that after three growing seasons in shelters there was no difference in diameter growth between sheltered and unsheltered trees for all ten tree species tested. Tree shelters have been widely used in Great Britain and other countries to cut costs of establishing small forest trees and Svihra et al. (1993) speculated they could be broadly used in nurseries and landscapes. Shoot growth of containerized Southern Magnolia (*Magnolia grandiflora*), Holly Oak (*Quercus ilex*), and Deodar Cedar (*Cedrus deodara*) was accelerated in tree shelters with no significant effects on caliper (12). Jones et al. (1996), in studying the use of plastic tree shelters for low-cost establishment of street trees, found that survival and growth of all species tested in shelters equaled or exceeded that of plants grown without shelters.

Blue-X tree shelters (McKnew Enterprises, Elk Grove, CA) are fabricated from partially transparent blue-tinted polyester film which reportedly gives them the unique characteristic of amplifying blue light and reducing UV light within the shelter. According to the manufacturer, the amplified blue light increases photosynthetically active radiation resulting in increased trunk diameter, in addition to enhanced transplant survival and accelerated growth in height. Our objective was to determine the effects of Blue-X tree shelters on height and caliper growth of tree-form crapemyrtle, with a goal of shortening production time.

Materials and Methods

Experiment 1. Three cultivars of commonly grown crapemyrtles, *Lagerstroemia indica ×fauriei* 'Tuscarora' [23 cm (9 in) tall] and *Lagerstroemia indica* 'Whitt II' Dynamite™ [10 cm (4 in) tall] and 'Potomac' [7 cm (3 in) tall], were transplanted on February 16, 2004, from 10.2 cm (4 in) liner pots into 11.4 L (#3) pots containing an 8:1 (by vol) pinebark:sand substrate 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. Plants were placed in full sun under overhead irrigation. Unsheltered trees were held upright with a single 152 cm (60 in) bamboo stake. Trees with shelters had two bamboo stakes used to support the tree and the shelter. Lateral branches of all trees were removed prior to placing 122 cm (48 in) tall Blue-X tree shelters over one half of the plants of each cultivar on March 26, 2004. The two treatments were replicated with 10 plants each and were completely randomized within cultivar. Height and caliper were measured and the presence of flowers noted monthly from April until October. Height was measured from the substrate surface to the highest point of the plant. Caliper was measured 2.5 cm (1 in) above the substrate surface with a digital caliper. On February 10, 2005, the three cultivars were repotted into 37.9 L (#10) pots containing the previously described substrate. The Blue-X tree shelters were removed and all plants were spaced in full sun under overhead irrigation. Height and caliper were recorded in April, June, August, and October. Data were subjected to analysis of variance (ANOVA) using SAS statistical software (SAS Institute, 2003).

Experiment 2. Liners of *Lagerstroemia indica* 'Whitt II' Dynamite™ [68 cm (26 in) tall] and 'Potomac' [57 cm (22 in) tall] were transplanted on February 16, 2005, into 11.4 L (#3) pots containing the same 8:1 (by vol) amended pinebark:sand substrate. Sheltered and unsheltered plants were staked similarly to experiment 1. Blue-X tree shelters, 122 cm (48 in), were installed on March 21, 2005, on half of the plants of each cultivar. The two treatments were replicated with 10 plants each and were completely randomized within cultivar. Plants were placed in full sun under overhead irrigation. Height, caliper, and flowering condition were recorded in April, June, August, and October. Floral characteristics of each plant was rated using a four part scale in which 1 = no visible floral development, 2 = visible floral development but no flower color, 3 = flower color present, and 4 = post color. Data were subjected to analysis of variance (ANOVA).

Results and Discussion

Dynamite™. Blue-X tree shelters promoted early and rapid shoot elongation of Dynamite™ in 2004 (Table 1). Sheltered plants were 95 and 86% taller in May and June than unsheltered plants. Accelerated shoot elongation continued after trees emerged from the top of the shelters (95, 118, and 128% greater than unsheltered plants in July, August, and September, respectively), probably because of a shelter-induced delay in flowering. In July, 30% of unsheltered plants were in flower, while none of the sheltered plants were in flower. By August, 60% of sheltered plants had flowered compared to 100% of unsheltered plants. Terminal flowering in crapemyrtle effectively ends shoot elongation (3, 9) as evidenced by the lack of height increase in unsheltered plants between July and October. By September, all sheltered, as well as unsheltered plants were flowering and little further increase in height occurred. Caliper growth also appeared closely linked to shelter treatment and flowering. By June, caliper of unsheltered plants was 29% greater than that of sheltered plants. The difference increased to 42% in July when flowering occurred in unsheltered plants. By August the difference had decreased to 12% and was not significant thereafter. In addition to effects on height, caliper, and flowering, sheltered plants appeared to have straighter trunks, less suckering from the base and little or no branching inside the shelters (Figure 1).

During the second year of the experiment, in which all plants were grown without shelters, previously sheltered Dynamite™ remained taller than unsheltered plants, although the magnitude diminished from 58% in June to 22% in October (Table 2) as branching increased at the expense of height growth. There were no differences in caliper or flowering between previously sheltered and unsheltered plants in 2005.

In the second experiment begun in April 2005, Dynamite™ performed much the same as in experiment 1, with early shoot growth promoted by the tree shelters and continued accelerated growth throughout the season. Plants grown in shelters were 58, 42, and 48% taller than unsheltered plants in June, August, and October, respectively (Table 3). By July 15, 100% of the unsheltered plants had flower color present [floral rating (FR) 3.0a], compared to 20% of the sheltered plants (FR 1.9b), similar to the flowering delay caused by the shelters in experiment 1 (Table 4). In September, 80% of the sheltered plants had flower color present (FR 3.2b) while 100% of unsheltered plants were post flower (FR 4.0a). There were no differences in caliper between the two treatments at any sampling in experiment 2. Comparable to experiment 1, Dynamite™ grown in shelters appeared to have straighter trunks, little to no lateral branching inside the shelters, and less suckering from the base, than that of plants grown without shelters (Figure 2).

'Potomac'. Contrary to Dynamite™, 'Potomac' had less rapid shoot elongation, with plants grown in shelters not surpassing unsheltered plants until August, 2004. Sheltered plants were 41 and 61% taller than unsheltered plants in September and October, respectively (Table 1). This continued shoot growth of sheltered plants in the latter part of the growing season is similar to that observed earlier in the season in Dynamite™ and appeared due to a shelter induced delay in flowering. By July, 50% of unsheltered 'Potomac' had flowered compared to no flowers on sheltered plants. All sheltered plants had flowered by September 2004. Similar to Dynamite™, no plants

flowered inside the shelters. Caliper growth appeared closely linked to shelter treatment and flowering with plants grown in shelters having 35, 34, and 25% less caliper than unsheltered plants in August, September, and October, respectively (Table 1). Plants grown in shelters appeared to have trunks that were straighter than unsheltered plants, little to no lateral branching inside the shelter, and less suckering from the base of the plant.

In the second year of the experiment in which all plants were grown without shelters, previously sheltered ‘Potomac’ continued to be taller than unsheltered plants at each sampling date. Similar to Dynamite™, ‘Potomac’ height differences diminished over the growing season with previously sheltered plants being 67% taller in April but only 16% taller in October (Table 2). There were no visible treatment-related differences in flowering of ‘Potomac’ in the second year. Caliper of plants in the two treatments was similar throughout the second year except for a 22% increase in unsheltered plants in June (Table 2). Plants grown in shelters the previous year continued to exhibit noticeably straighter trunks.

Treatment effects on height of ‘Potomac’ were evident earlier in experiment 2 than in experiment 1. Sheltered plants were 50, 55, and 50% taller than unsheltered plants in June, August, and October, respectively (Table 3). As with Dynamite™ in experiment 2, there were no differences in caliper between sheltered and unsheltered plants at any sampling date. On August 15, 50% of ‘Potomac’ grown in shelters were showing flower color (FR 2.0b) compared to 100% of unsheltered plants (FR 3.0a) (Table 4). By October, all plants were at post color (FR 4.0). Similar to Dynamite™ in experiments 1 and 2, and ‘Potomac’ in experiment 1, sheltered plants appeared to have straighter trunks, less suckering from the base and little or no branching inside the shelters.

'Tuscarora'. Height of 'Tuscarora' was not significantly influenced by the Blue-X tree shelters in experiment 1 except for a 32% decrease of sheltered plants in June. Although not significant, a trend of increased growth for plants grown in shelters did exist from August to October. Caliper of 'Tuscarora' was 47, 35, and 28% less in July, August, and September when grown in shelters (Table 1). West et al. (1999) reported that shelters had a negative effect on basal diameter of flowering dogwood (*Cornus florida*) and Chinese elm (*Ulmus parvifolia*) after two years growth in the field. However, by the end of the 2004 season, calipers of sheltered and unsheltered 'Tuscarora' were similar. The diminishing differences in caliper may be attributed to the delay in flowering caused by the tree shelters allowing more caliper growth of sheltered plants as the season progressed. 'Tuscarora' exhibited similar flowering characteristics as Dynamite™ and 'Potomac' in response to the treatments, with plants grown in shelters flowering later than the controls and no flowering occurring inside the shelters. By July, 80% of the unsheltered plants had flowered with no flowering of sheltered plants. Terminal flowering ended shoot elongation in 'Tuscarora' as evidenced by the lack of height increase from July through October, while sheltered plants with delayed flowering continue to increase in height. All plants in both treatments had flowered by September.

In the second year of the experiment in which all plants were grown without shelters, 'Tuscarora' continued to have no significant treatment effect on height. There were no differences in caliper from June to October and no difference in flowering characteristics between the two treatments. Visual differences between the plants were apparent, with sheltered plants having straighter trunks and less lateral branching up to the previous height of the shelters.

All cultivars tested responded to the Blue-X tree shelters, with increased height, reduced caliper, or both. Dynamite™ and ‘Potomac’ but not ‘Tuscarora’ had a positive response to the shelters. Dynamite™ and ‘Potomac’ are intra-specific whereas ‘Tuscarora’ is an inter-specific hybrid. The difference in response of inter-specific cultivars and intra-specific cultivars to the tree shelters was not studied in these tests but could warrant further investigation. Caliper of Dynamite™ was not affected by shelters at the end of the 2004 season, whereas ‘Potomac’ exhibited a slight reduction in caliper in when grown in shelters (Table 1). However, caliper differences in ‘Potomac’ were not evident at three of the four sampling dates in the year after removing the shelters. Caliper of Dynamite™ and ‘Potomac’ was not affected by the shelters in the 2005 experiment (Table 3). ‘Tuscarora’ grown in shelters had significantly less caliper growth than unsheltered plants throughout much of the 2004 growing season. According to the manufacture, the amplified blue light of the Blue-X tree shelters encourages diameter growth. Clear plastic tree-shelters have been shown to limit caliper growth of some species (5, 12). Caliper effects of tree-shelters are species specific and can be positive or negative (10).

Plants of all cultivars in both experiments grown inside the tree shelters had noticeably straighter, more upright trunks than unsheltered plants with little to no lateral branching inside the shelters (Figure 2). Dynamite™ and ‘Potomac’, with shelters removed at the beginning of the second growing season, were beginning to lose some of the height advantage caused by the shelters the previous year. Of the three cultivars tested, none flowered inside the tree shelters. However, once plants reached the top of the tree shelters the flowering process appeared to be initiated. Overall each cultivar grown in tree shelters flowered at a later date than did unsheltered plants.

An assessment of costs related to container production of crapemyrtles with and without tree shelters may be helpful to nursery producers interested in using tree shelters during nursery crop production. As of 2005, 122 cm (48 in) Blue-X tree-shelters, the type used in our study, ranged from $1.19 each for less than 100 to $0.79 for 5,000 or more. In nursery situations, shelters may be helpful in training attractive trees with less labor. Blue-X tree shelters significantly increased height growth in two of the three cultivars tested without affecting caliper at the end of the growing season and resulting in straighter, more upright trunks in all cultivars tested. Growing crapemyrtles in Blue-X tree shelters may shorten production time of tree-form by enhancing height growth or improving plant form.

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Table 1. Height and caliper of three container-grown crapemyrtle cultivars grown in Blue-X tree shelters in Auburn, AL, experiment 1, 2004.

Treatment	Height (cm)							Caliper (mm)						
Dynamite™														
	Apr.	May	June	July	Aug.	Sept.	Oct.	Apr.	May	June	July	Aug.	Sept.	Oct.
(-) Shelter	12.7	31.9	48.8	74.5	76.7	76.2	78.0	3.6	4.8	6.2	9.8	10.4	10.6	11.2
(+) Shelter	14.3	62.3	90.7	145.2	167.2	174.0	174.5	3.8	4.7	4.8	6.9	9.3	10.8	11.9
Significance[z]	*	**	*	**	***	***	***	NS	NS	**	**	*	NS	NS
'Potomac'														
	Apr.	May	June	July	Aug.	Sept.	Oct.	Apr.	May	June	July	Aug.	Sept.	Oct.
(-) Shelter	6.6	25.2	41.4	84.7	87.7	88.2	87.4	3.2	3.0	4.7	8.9	9.7	10.1	10.4
(+) Shelter	7.7	21.9	37.0	69.1	98.9	124.7	140.4	3.2	3.2	3.2	4.0	6.3	6.7	7.7
Significance	NS	NS	NS	NS	NS	*	**	NS	NS	***	***	**	**	*
'Tuscarora'														
	Apr.	May	June	July	Aug.	Sept.	Oct.	Apr.	May	June	July	Aug.	Sept.	Oct.
(-) Shelter	32.6	71.1	116.3	139.8	137.2	137.3	146.5	3.8	8.3	11.6	14.6	15.1	16.3	16.3
(+) Shelter	38.4	55.8	78.8	122.7	161.1	169.5	169.9	3.6	4.8	5.8	7.6	9.8	11.8	13.5
Significance	NS	NS	**	NS	NS	NS	NS	NS	***	***	***	**	**	NS

[z]NS, *, **, and *** represent non-significant, and significant effects where $P \leq 0.05$, 0.01, and 0.001, respectively.

Table 2. Height and caliper of three container-grown crapemyrtle cultivars in the year following growth in Blue-X tree shelters in Auburn, AL, experiment 1, 2005[z].

Treatment	Height (cm)				Caliper (mm)			
Dynamite™								
	Apr.	June	Aug.	Oct.	Apr.	June	Aug.	Oct.
(-) Shelter	78.0	106.5	146.9	152.0	11.2	12.5	18.1	19.1
(+) Shelter	174.5	169.0	184.7	185.8	11.9	13.8	16.9	18.0
Significance[y]	***	***	***	***	NS	NS	NS	NS
'Potomac'								
	Apr.	June	Aug.	Oct.	Apr.	June	Aug.	Oct.
(-) Shelter	87.4	122.5	169.6	171.8	10.4	12.8	17.4	18.7
(+) Shelter	146.3	162.2	198.2	199.6	7.9	10.5	14.0	16.1
Significance	**	***	***	***	NS	**	NS	NS
'Tuscarora'								
	Apr.	June	Aug.	Oct.	Apr.	June	Aug.	Oct.
(-) Shelter	146.5	177.9	221.9	225.5	16.3	18.3	22.7	24.7
(+) Shelter	169.9	188.6	212.4	228.1	13.2	15.7	22.0	24.0
Significance	NS	NS	NS	NS	*	NS	NS	NS

[z]Tree shelters were removed in March 2005.
[y]NS, *, **, and *** represent non-significant, and significant effects where $P \leq 0.05$, 0.01, and 0.001, respectively.

Table 3. Height and caliper of two container-grown crapemyrtle cultivars grown in Blue-X tree shelters in Auburn, AL, experiment 2, 2005.

Treatment	Height cm				Caliper mm			
	Dynamite™							
	Apr.	June	Aug.	Oct.	Apr.	June	Aug.	Oct.
(-) Shelter	66.4	89.0	126.8	126.5	5.1	7.0	12.6	14.6
(+) Shelter	72.0	140.4	179.7	187.8	5.3	6.3	12.9	15.1
Significance[z]	**	***	***	***	NS	NS	NS	NS
	'Potomac'							
	Apr.	June	Aug.	Oct.	Apr.	June	Aug.	Oct.
(-) Shelter	58.0	67.8	133.6	141.7	5.3	5.7	13.7	15.5
(+) Shelter	57.2	101.8	207.2	213.2	5.2	5.7	13.0	13.5
Significance	NS	**	**	**	NS	NS	NS	NS

[z]NS, *, **, and *** represent non-significant, and significant effects where $P \leq 0.05$, 0.01, and 0.001, respectively.

Table 4. Flower ratings[z] of two container-grown crapemyrtle cultivars grown in Blue-X tree shelters in Auburn, AL, experiment 2, 2005.

Treatment	Dynamite™						'Potomac'					
	May	June	July	Aug.	Sept.	Oct.	May	June	July	Aug.	Sept.	Oct.
(-) Shelter	1.0	1.1	3.0	3.8	4.0	4.0	1.0	1.0	1.9	3.0	3.2	4.0
(+) Shelter	1.0	1.0	1.9	2.8	3.2	4.0	1.0	1.0	1.0	2.0	2.8	4.0
Significance[y]	NS	NS	**	**	***	NS	NS	NS	*	*	NS	NS

[z]Flower Rating Scale, 1 = no visible floral development, 2 = visible floral development but no flower color, 3 = flower color present, and 4 = post color.
[y]NS, *, **, and *** represent non-significant, and significant effects where $P \leq 0.05$, 0.01, and 0.001, respectively.

Figure 1. Dynamite™ grown in Blue-X tree shelters in Auburn, AL.

Figure 2. Dynamite™ with Blue-X tree shelters removed.