Growth and Foliar Nutrient Concentrations of Crape Myrtle in Response to Disparate Climate and Fertilizer Placement in Large Nursery Containers[1]

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Abstract

A study was replicated in different climates [central Arizona (arid, Sonoran desert) and southwestern Georgia (humid, temperate)] to evaluate effects of controlled-release fertilizer placement in a bark-based container substrate on growth and foliar nutrient concentrations of *Lagerstroemia indica* L. x *L. fauriei* Koehne 'Muskogee' in large (#7) containers. Plants in Arizona were smaller with higher shoot-to-root ratios and higher levels of N, K, P, Fe, and Cu and lower levels of Ca and Zn in foliage compared with plants in Georgia. Differences in meteorological factors such as higher maximum and minimum temperatures and solar radiation, lower rainfall, and higher container root-zone temperatures, leachate electrical conductivity and nitrate concentrations were coincident with the smaller size and higher foliar nutrient concentration of Arizona plants. Fertilizer placed at the north exposure of container substrate increased plant size in Arizona. However, compared with growth of plants in Georgia, fertilizer placement at the north exposure in Arizona was not enough to entirely alleviate size inhibition caused by the arid Sonoran desert climate.

Index words: heat stress, nursery production, nutrition.

Species used in this study: Muskogee crape myrtle (*Lagerstroemia indica* L. x *L. fauriei* Koehne 'Muskogee').

Significance to the Nursery Industry

Supraoptimal temperatures inhibit growth in outdoor container nurseries in the southern United States. This research demonstrates that extremely high aerial and root-zone temperatures in arid, central Arizona sharply inhibited growth but did not impair nutrient uptake and, in fact, resulted in a foliar nutrient concentrating effect compared with plants grown in humid, temperate, southwestern Georgia. In Arizona, controlled-release fertilizer placed at the north exposure of container substrate increased shoot size, while fertilizer placed top-dressed or at the west exposure increased root dry weight. In Georgia, fertilizer top-dressed increased plant size for the first 2.5 months of the experiment. However, location of controlled-release fertilizer placement in the container substrate had no effect on dry weight of Georgia plants. Based on these findings, nursery operators in the hot, arid, southwestern United States may in addition to conventional top dressing practices consider placement of controlled-release fertilizer at the north exposure of large containers as part of a cultural management system to increase shoot size. In the humid, temperate, southeastern United States, fertilizer placement as part of a management system in larger containers does not appear to offer as much benefit to nursery operators.

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Introduction

Root-zone temperatures above 40C (104F) in container substrates in outdoor production nurseries cause direct or indirect injury of roots and subsequent reductions in growth and market quality (3). High container root-zone temperatures are caused by a combination of climate-mediated factors such as intensity of solar radiation striking container walls, air temperature, relative humidity and wind speed (4). In previous research, Ruter and Martin (11) found that growth and water use of container-grown *Ligustrum* and *Feijoa* were less for plants grown in an arid, Sonoran desert climate compared with those in a humid, temperate climate, even though plants at both locations received identical horticultural practices.

Root growth in sun-exposed containers occurs mostly in portions of container substrates where temperatures are moderated at or below 40C (104F) such as the north exposure (6). In full sun, container root-zone temperature patterns are dynamic and are appertained by an interaction of climate with container albedo, proximity to the container wall, rooting substrate composition, water content and time of year (4, 5). Placement of controlled-release fertilizers in container substrate where root growth is localized due to patterns of supraoptimal root-zone temperatures might improve fertilizer-use efficiency and plant size, a response that might be augmented in a hot climates.

Root-zone temperatures > 40C (104F) in pine bark substrates can lower rates of nitrification and for some species might result in foliar nutrient imbalances induced by increased concentrations of NH_4^+-N (7, 12). This problem of high temperature inhibition of nitrification might also be lessened by optimizing fertilizer placement in container substrates zones where root-zone temperatures are lower. Thus, our objective was to investigate effects of controlled-release fertilizer placement in container substrate on plant growth and foliar nutrient concentrations in two disparate climates [central Arizona (arid, Sonoran desert) and southwestern Georgia (humid, temperate)].

Materials and Methods

Research was conducted outdoors under full sun at the Arizona State University Horticultural Resource Center in Tempe (33.5N 112W) and the University of Georgia Coastal Plain Experiment Station in Tifton (32N 83W). Same-source, uniform rooted liners of *Lagerstroemia indica* x *fauriei* 'Muskogee', trimmed to 0.2 m (8 in) height, were potted into #7 black polyethylene containers on May 1, 1994. The rooting substrate consisted of pine bark and sand (8:1 by vol) amended with Micromax micronutrients at 0.9 kg/m^3 (1.5 lb/yd^3). After potting, plants were fertilized with 16N–3.0P–10.0K (16–7–12) controlled-release fertilizer formulated for a 10-month release according to one of six different fertilizer placement treatments. Fertilizer treatments consisted of 360 g/pot (23 lb/yd^3) placed in a cylindrical configuration 0.02 m (0.8 in) below the rooting substrate surface at either the 1) east, 2) south, 3) west, or 4) north cardinal coordinates or 5) 90 g of fertilizer placed in a cylindrical configuration 0.02 m (0.8 in) below the rooting substrate surface at the east, south, west and north cardinal coordinates or 6) 360 g of fertilizer top-dressed on the rooting substrate surface. Plants at both locations were then grown for 5 months on black polypropylene fabric at a spacing distance of 0.9 m (36 in) between exterior walls and irrigated to container capacity each day in the early morning irrespective of previous rainfall events. Irrigation water electrical conductivity (EC) was 1.1 and 0.2 dS/m in Arizona and Georgia, respectively.

Meteorological variables of daily maximum and minimum air temperatures and rainfall were collected at each location and averaged for each month (Table 1). Average daily maximum temperatures in Arizona ranged from 5.9 to 11.2C (10.7 to 20.1F) higher than in Georgia, while minimum daily temperatures were 0.6 to 7.0C (1.0 to 12.6F) higher in Arizona. Rainfall for the 5 months totaled 62 mm (2.48 in) in Arizona and 714 mm (28.58 in) in Georgia. Container substrate temperatures were also recorded with a 21X micrologger (Campbell Scientific, Inc., Logan, UT) and AM32 multiplexer (Campbell Scientific, Inc., Logan, UT) on days typical of fair weather during summer; full sun in Arizona and periods of sun interspersed with clouds in Georgia. Welded copper constantan thermocouples were positioned one-half way down the container profile at the east, south, west, and north cardinal coordinates, 0.02 m (0.8 in) from the rooting medium/container wall interface, and at the center location. In Arizona, the highest recorded bark substrate temperature was 63C (145F) at the west exposure and remained above 40C (104F) for 6.3 hours (Fig. 1a). In contrast, the highest recorded bark substrate temperature at

Table 1. Mean monthly maximum (T_{max}) and minimum (T_{min}) temperatures and monthly rainfall for Arizona and Georgia, respectively, during Spring and Summer 1994.

Month	Arizona T_{max} (C)	Arizona T_{min}	Arizona Rain (mm)	Georgia T_{max} (C)	Georgia T_{min}	Georgia Rain (mm)
May	33.1	15.7	7.8	27.2	15.2	33.3
June	40.9	23.2	0.3	29.8	20.5	214.3
July	40.9	25.7	5.5	30.3	20.9	191.8
August	41.7	27.0	5.3	30.3	20.0	128.5
September	37.6	21.8	39.5	28.6	17.8	97.5

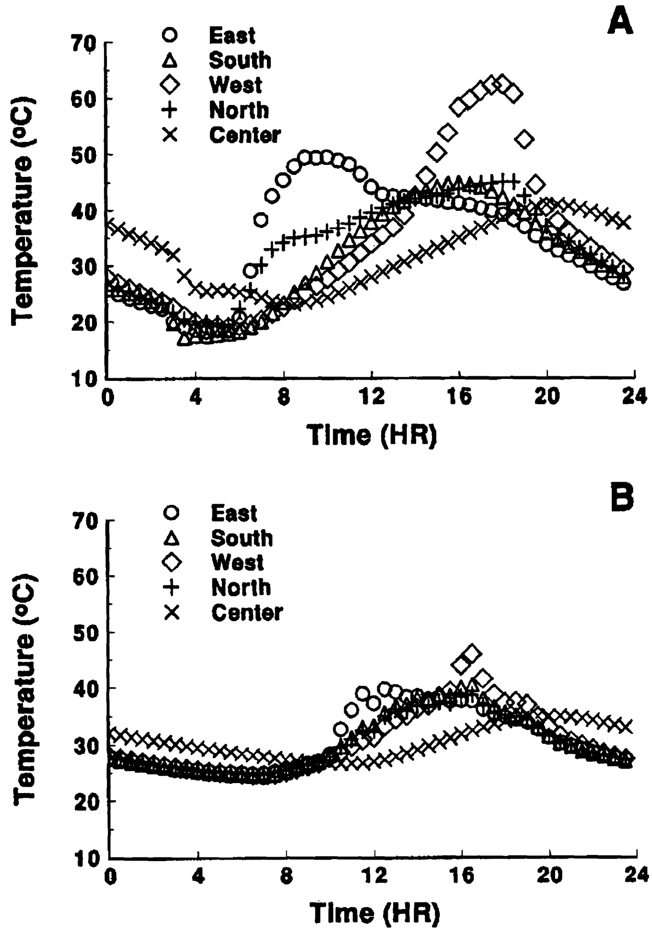

Fig. 1. Root-zone temperatures in container substrate [pine bark:sand (8:1 by vol)] in (A) Arizona or (B) Georgia. Root-zone temperatures in Arizona and Georgia were recorded on June 14 and June 20, respectively, n = 4.

the Georgia location was 45C (113F) at the west exposure and remained above 40C (104F) for only 1.5 hours (Fig. 1b). Diurnal air temperatures and irradiance flux were also recorded at both locations coincident with root-zone temperatures (Fig. 2). Irradiance data were collected with a LI-200SA pyranometer sensor (LI-COR, Inc., Lincoln, NB).

Plant height and widths in the north-south (width1) and east-west (width2) orientation were measured monthly. Shoot size indices [(height + width1 + width2) / 3] were calculated for each month. Container substrate leachate was also collected monthly by use of the pour-through nutrient extraction procedure (13) and analyzed for pH, EC, and NO_3-N using a nitrate ion specific electrode (Orion Research Inc., Boston, MA). The study was terminated after five months and shoot and root dry weights and foliar nutrient levels determined at the University of Georgia's Coastal Plain Experiment Station (2).

The experiment was a two location × six fertilizer treatment factorial arranged in a randomized complete block design with 10 single plant replicates of which equaled 60 plants at each location. General linear models procedures were used to test for significant responses of the variables. Repeated measures analysis was used to compare changes in growth indices over time as affected by treatments.

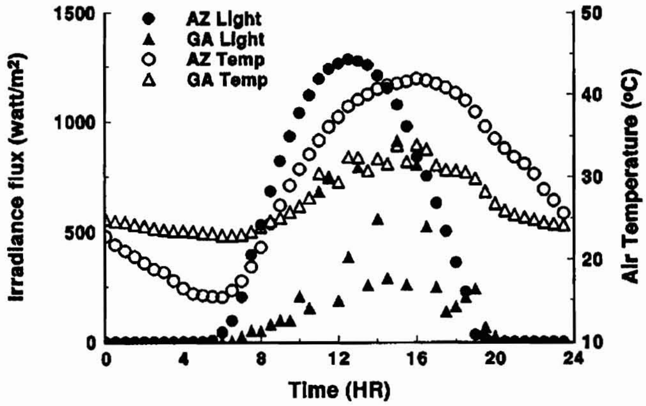

Fig. 2. Irradiance flux (AZ Light and GA Light, respectively) and air temperatures (AZ Temp and GA Temp, respectively) for Arizona on June 14, 1994, and Georgia on June 20, 1994.

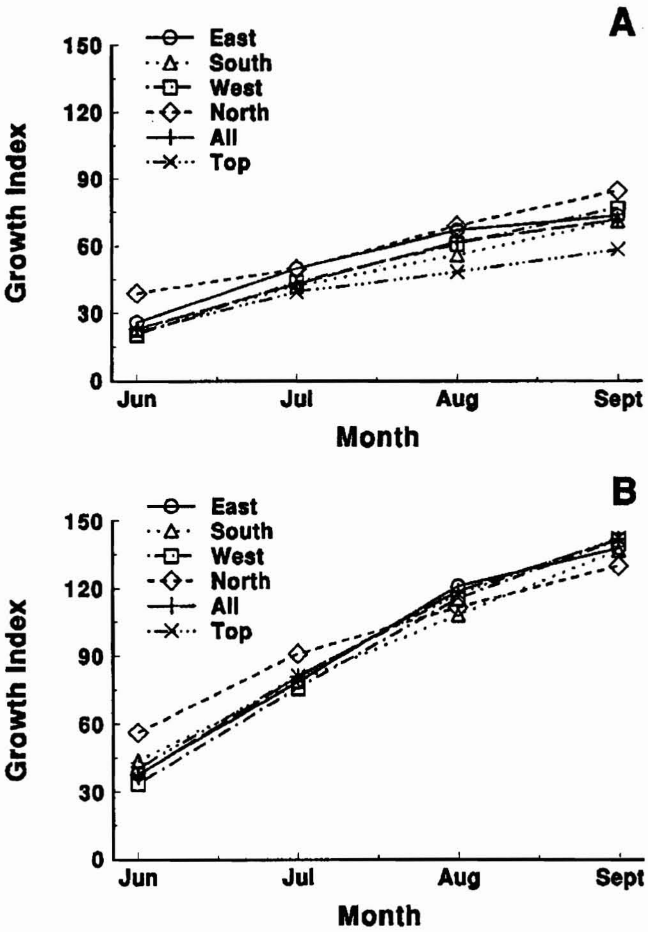

Fig. 3. Size indices [(height + width1 + width2 / 3)] of crape myrtle in Arizona or Georgia during Spring and Summer 1994 as affected by controlled-release fertilizer treatments using repeated measures analysis. Fertilizer placement treatments of plants grown in (A) Arizona or (B) Georgia consisted of 360 g fertilizer placed 0.02 m (0.8") below the rooting substrate surface at the 1) east, 2) south, 3) west, or 4) north cardinal coordinates, or 5) 90 g of fertilizer placed 0.02 m (0.8") below the rooting substrate surface at the north, east, south, and west cardinal coordinates (all), or 6) 360 g of fertilizer top-dressed on the rooting substrate surface (top).

Table 2. Repeated measures analysis of variance of significant polynomial time trends and treatments contrasts for size index [(height + width + width / 3)] of crape myrtle grown in Arizona or Georgia in response to controlled-release fertilizer treatments during Spring and Summer, 1994.

Source of variation	dF	MS	F	P values[z]
Arizona				
Fertilizer[y] × Time				
4 vs. 1, 2, 3, 5, 6	1	399.7	12.0	0.0012 Q
6 vs. 1, 2, 3, 4, 5	1	896.4	13.7	0.0006 L
Georgia				
Fertilizer × Time				
4 vs. 1, 2, 3, 5, 6	1	4165.5	16.4	0.0002 L

[z]Linear (L) or quadratic (Q) fitted line responses across time.

[y]Treatment contrasts for controlled-release fertilizer placement are 360 g fertilizer placed 0.02 m (0.8") below the rooting substrate surface at the 1) east, 2) south, 3) west, or 4) north cardinal coordinates, or 5) 90 g of fertilizer placed 0.02 m (0.8") below the rooting substrate surface at the north, east, south, and west cardinal coordinates, or 6) 360 g of fertilizer top-dressed on the rooting substrate surface.

Results and Discussion

In Arizona, shoot size was largest for plants with fertilizer placed in the north quadrant and lowest for plants with fertilizer top-dressed on the container substrate surface (Table 2, Fig 3a). In Georgia, shoot size indices were initially highest for plants with fertilizer placed in the north exposure; however, fertilizer placement had no effect on shoot size after 5 months (Table 2, Fig. 3b). At the end of the experiment, size indices of Georgia plants were about 2.0 times larger than for those in Arizona (Fig 3).

Shoot dry weights of plants in Georgia were about 6.0 times greater than for those in Arizona, while root dry weights of Georgia-grown plants were about 11.0 times greater than for those in Arizona. These response patterns of container plants grown under disparate climates were similar to earlier findings of Ruter and Martin on *Feijoa Sellowiana* and *Ligustrum japonicum* (11). Roots of Georgia plants were concentrated in the north, center and bottom portions of the container substrate, while roots of Arizona plants were concentrated entirely at the container bottom (visual observation at harvest). In Arizona, root dry weight was greatest for plants with fertilizer top-dressed or placed at the west exposure (Table 3). Root dry weight was least for plants with fertilizer placed equally at the east, south, west, and north exposures. Fertilizer placement did not affect shoot dry weight or shoot to root ratio at either location and root dry weight of Georgia plants (Table 3). These data demonstrate a poor correlation between crape myrtle shoot size and shoot biomass accumulation because the size index used in this experiment did not account for differences in canopy density or stem caliper.

In Arizona, mean monthly NO_3-N concentrations in container substrate ranged from 111 to 201 mg/liter, while mean monthly EC values ranged from 2.3 to 3.1 dS/m. In Georgia, NO_3-N concentrations in container substrate ranged from 64 to 127 mg/liter, while EC ranged from 0.8 to 1.2 dS/m. Although a positive relationship between NO_3-N concentration and EC in leachate of containers containing controlled-release fertilizer has been formerly documented (9), higher NO_3-N concentrations in Arizona container leachate than

Table 3. Response of crape myrtle shoot dry weight (SDW), root dry weight (RDW), shoot:root ratio (S:R) to controlled-release fertilizer treatments in Arizona or Georgia during Spring and Summer 1994.

Location Fertilizer[z]	SDW (g/plant)	RDW (g/plant)	S:R
Arizona			
East	61.9a[y]	31.0bc	2.0a
South	93.7a	57.1ab	1.6a
West	107.2a	62.1a	1.7a
North	80.8a	49.4abc	1.6a
All	58.7a	26.0c	2.3a
Top dress	108.2a	64.8a	1.7a
Georgia			
East	244.0a	226.0a	1.1a
South	295.4a	351.4a	0.8a
West	300.7a	283.5a	1.1a
North	299.6a	297.5a	1.0a
All	313.3a	237.5a	1.3a
Top dress	326.6a	379.2a	0.9a

[z]Fertilizer placement treatments consisted of 360 g fertilizer placed 0.02 m (0.8") below the rooting substrate surface at the 1) east, 2) south, 3) west, or 4) north cardinal coordinates, or 5) 90 g of fertilizer placed 0.02 m (0.8") below the rooting substrate surface at the north, east, south, and west cardinal coordinates, or 6) 360 g of fertilizer top-dressed on the rooting substrate surface.

[y]Values are treatments means for SDW, RDW, and S:R, respectively. For each location, mean separation within columns by Duncan's multiple range test, P = 0.05, n = 5.

in Georgia may be due to a combination of higher irrigation EC, lower summer rainfall and higher controlled-release fertilizer release rates. Leachate pH was not affected by fertilizer placement and was between 6.1 and 6.6 at both locations. Container substrate leachate EC and NO_3-N were not affected by fertilizer placement at either location.

Nutrient levels in foliage of crape myrtle at both locations were sufficient for normal plant growth (1). Furthermore, foliar levels of N, K, P, Fe, and Cu were higher for plants in Arizona compared with those in Georgia (Table 4). In contrast, foliar levels of Ca and Zn were higher for plants grown in Georgia and foliar levels of Mg and Mn were not affected by growing location. Other researchers have found reduced Mn in foliage of plants fertilized with nitrogen at > 50% derived from NH_4-N and urea and exposed to supraoptimal root-zone temperatures, apparently due to increased container substrate solution pH and inhibition of nitrification (7, 12). Controlled-release fertilizer used in this study contained nitrogen derived from 54% NH_4-N and 46% NO_3-N, yet we found no negative effects of supraoptimal temperatures on foliar sequestration of Mn or other elements at either growing location.

We conclude that extremely high aerial and root-zone temperatures in Arizona did not impair nutrient uptake, and in fact resulted in a foliar nutrient concentrating effect due to less growth and utilization by plants compared with plants grown in Georgia. Size suppression of Arizona plants compared with Georgia plants may have been related to factors other than nutrient uptake and plant nutrition such as 1) higher leaf-to-air vapor pressure gradients decreasing leaf conductance and photosynthesis (8), 2) higher specific root and shoot maintenance respiratory metabolism (10), and/or 3) possible alterations in root-to-shoot hormone signals causing nonstomatal limitation to photosynthesis (14).

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Table 4. Macronutrient and micronutrient levels[z] in crape myrtle leaves grown in Arizona or Georgia.

	Macronutrients					Micronutrients			
Location	N	P	K	Ca	Mg	Fe	Zn	Mn	Cu
	(%)					(µg/g)			
Arizona	3.99[y]	0.36	1.75	1.16	0.78	106	66	336	5.1
Georgia	2.85	0.29	1.08	1.36	0.76	66	91	366	4.1
Significance[x]	***	**	***	*	NS	***	**	NS	*

[z]Foliar samples were analyzed in a common lab at the University of Georgia.

[y]Values are treatments means, n = 6.

[x]Nonsignificant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.