Effects of Above-Ground Pot-in-Pot (PIP) Placement and Humic Acid Extract on Growth of Crape Myrtle[1]

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Abstract

Rooted cuttings of crape myrtle (*Lagerstroemia indica* L. x *L. fauriei* Koehne 'Muskogee') were potted into 3.8 liter (1 gal) black polyethylene containers and subjected for two months to one of three above-ground shielding treatments; containers placed pot-in-pot (PIP) for two months, containers exposed to direct sunlight for two months, or containers placed PIP for one month and then exposed to sunlight for one month (PIP/exposed). Mean daily maximum temperatures in rooting substrate of containers exposed to sunlight were as much as 16C (29F) higher than PIP containers. Plants in containers exposed to sunlight for two months had less total root and shoot length and higher concentrations of leaf nitrogen compared with the other two treatments. Plants were next transplanted into 27-liter (7-gal) polybags filled with a landscape substrate and fertigated with a humic acid extract at 0, 50, 150, or 300 μL/L for two additional months. The change in shoot and root length of plants previously placed PIP for two months responded in quadratic fashion to increased humic acid extract concentration levels; the most response occurred at about 50 μL/L while the highest concentrations inhibited post-transplant growth. Growth inhibition caused by heat stress as a result of exposure of container walls to insolation was still evident two months after transplanting.

Index words: biostimulant, heat stress, landscape, nursery production, transplanting.

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

Significance to the Nursery Industry

Placement of nursery containers in an above-ground PIP system reduced the occurrence of supraoptimal rooting substrate temperatures above 40C (104F). Plants in containers placed PIP were larger than plants in nursery containers exposed to sunlight, a pattern that was still evident two months after transplanting into a landscape substrate. Although plants in PIP/exposed containers were the same size as plants in PIP containers before transplanting, growth inhibition of the former treatment was evident two months after transplanting. Post-transplant shoot growth of plants previously in PIP containers was stimulated by regular applications of a humic acid extract at 50 μL/L. However, humic acid treatments did not affect growth of plants previously in exposed or PIP/exposed containers. Based on our results, nursery operators in the southern United States might use an above-ground PIP system to lower container substrate temperatures and improve plant growth during nursery production and after transplanting in the landscape. Although humic acid extract stimulated post-transplant growth of plants previously in PIP containers, it should not be viewed as a biostimulant for heat-stressed roots.

Introduction

Temperatures above 40C (104F) in container substrates in outdoor nurseries are caused mostly by exposure of the container outer wall to direct sunlight, and are a principal deterrent to plant growth (3, 5). Nursery practices that reduce the incidence and/or absorption of solar radiation energies by container walls include modifying container spacing patterns, altering container exterior color and shape, and growing plants in shade of an overhead canopy (5). Placing plants in PIP containers has been used in below-ground systems to buffer roots from rapid temperature fluctuations (12). Advantages of an above-ground PIP system include shielding container walls from direct sunlight while maintaining grower production flexibility as containers are placed inside a holder pot on the ground. Unlike below-ground PIP, above-ground PIP systems do not reduce container blow over or protect roots from freezing temperatures. Thus, this system is best suited for production of smaller plant materials in areas of mild winters and warm-to-hot summers, such as occur in the southern United States.

Rapid root regeneration accelerates post-transplant establishment of plants in landscapes (2). Root growth of plants in nursery containers was inhibited for as long as 16 weeks after exposure to supraoptimal temperatures (8). One method for increasing post-transplant root growth might involve applications of humic substances mixed in irrigation water or in granular form to backfill substrates of landscape transplant holes. Humic acid has been shown to stimulate growth through changes in auxin activity (11, 14). Objectives of this study were to 1) determine the effectiveness of above-ground PIP containers on plant growth, and 2) ascertain effectiveness of a commercial humic acid extract product on biostimulation of post-transplant growth of plants previously differentially heat stressed by container shielding treatments.

Materials and Methods

Research was conducted at the Arizona State University Horticulture Resource Center in Tempe (33.5N 112W; USDA hardiness zone 9). Uniform softwood cuttings of 'Muskogee' crape myrtle (*Lagerstroemia indica* x *L. fauriei* 'Muskogee'), trimmed to 15 cm (5.9 in), were potted on June 12, 1995 into 3.8 liter (1 gal) black polyethylene containers containing a blend of Omni-mix (Western Organics, Phoenix, AZ), Gilman clay loam (pH = 7.3; EC = 0.25 dS/m; 13.2 g organic matter/kg soil), and silica sand (particle diameter ≤4.3 mm) (3:1:1 by vol) and placed outdoors under full sun on a black polypro-

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pylene fabric groundcover (Dewitt's Pro-5, Sikestone, MO). Each plant was top-dressed with 15 g (0.6 oz) of 14N–6.2P–11.6K (14–14–14) controlled-release fertilizer formulated for a 4-month release rate plus 1 g (0.04 oz) of Micromax micronutrient fertilizer (Scotts Co., Marysville, OH). All plants were watered in excess of container capacity via an overhead irrigation system each day at 0300 HR.

After potting, containers were positioned at 61 cm (24 in) on center in one of three above-ground container shielding treatments. The treatments included; 1) PIP for 2 months [3.8 liter (1 gal) black polyethylene container placed inside a whitewashed 11 liter (3 gal) black polyethylene container], 2) 3.8 liter black polyethylene containers exposed for 2 months to sunlight without shielding, and 3) containers placed PIP for one month and then exposed to sunlight for one month (PIP/exposed).

Total shoot length (meter/plant) of all plants was measured monthly. Rooting substrate temperatures were recorded halfway down the container profile in the center and 2 cm (0.8 in) from the east and west container walls using copper constantan thermocouples connected to a 21X micrologger (Campbell Scientific, Inc., Logan, UT). Temperature data were recorded June 22–23, July 8–9, and August 9–10 during clear, cloudless weather conditions. Trapezoidal integration was used to calculate the mean number of degree-hours (C-hr) per day above 40C (104F).

After two months, four plants from each shielding treatment were selected randomly for harvest. Root systems were severed at the soil line and carefully washed. Total root length was measured with a digital imaging system (Decagon Devices, Pullman, WA). Roots and shoots were then oven-dried at 70C (158F) for 48 h and weighed. Leaves were analyzed for nitrogen concentration (1).

The three shielding treatments were arranged in a randomized complete block design with six blocks of six plants each for a total of 108 plants. General linear models procedures were used to test for significant responses of the variables. Duncan's multiple range test was used to separate shielding treatment effects on shoot and root dry mass. Repeated measures analysis was used to compare increases in total shoot length over time as affected by shielding treatments.

All remaining plants were removed (rootballs undisturbed) from 3.8 liter (1 gal) containers, their rootballs wrapped in a single layer of 1.6 cm (0.63 in) mesh netting (Easy Gardener, Waco, TX), and transplanted into 27 liter (7 gal) plastic grow bags with drainage holes (McCalif Grower Supplies, Inc., Ceres, CA) filled with a river sand and Gilman clay loam substrate (4:1 by vol) to simulate a landscape transplant situation. Transplants were then grown in a temperature-controlled glasshouse [29C (84F) day/21C (70F) night, 40% light exclusion at solar noon, no humidity control] and the natural photoperiod was extended with 3 hr (2000 to 2300 HR) of incandescent lighting at 90 cm (35.4 in) above average canopy] for two additional months before final harvest. Substrate temperatures were between 23C (73F) and 27C (81F).

Plants were fertigated with "Forest Magic" Jenner 8 (Catalyst Prod. Group, Buckeye, AZ), a commercial humic acid extract [4% humic acid minimum derived from leonardite and digested bovine manure leachate; composed of 479 μL/L organic nitrogen, 9 μL/L nitrate-nitrogen, < 200 μL/L total phosphorous (P_2O_5), 2,800 μL/L total potassium (K_2O_5), 2.2 μL/L copper, 180 μL/L iron, 4.5 μL/L manganese, and 2.2 μL/L zinc; pH = 9.0; EC = 5.9 dS/m], mixed with deionized irrigation water in one of four treatment concentrations; 0, 50, 150, or 300 μL/L. A Dosmatic-Plus liquid injector (Dosmatic USA, Carrollton, TX) attached to a drip irrigation system supplied 1800 ml (61 oz) of a deionized water/liquid humic acid extract solution per application, which occurred every three days. Soil moisture potential of the transplant substrate was always > –0.02 MPa as measured with soil tensiometers (Soilmoisture Equip. Inc., Santa Barbara, CA)

At final harvest, total shoot length was measured and the change in shoot length was calculated as total shoot length at final harvest minus total shoot length at transplanting into 27 liter containers. Shoots were then severed at the soil line, and roots were divided into inner roots (within the netting wrap from the original container), and outer roots (roots which grew beyond the netting into the transplant soil). Total length of outer roots was measured. Inner and outer roots and shoots were then oven dried and weighed.

This part of the experiment was a three previously-shielded treatments by four humic acid extract concentrations factorial arranged in a randomized complete block design with seven single plant replications for a total of 84 plants. General linear models procedures were used to test for signifi-

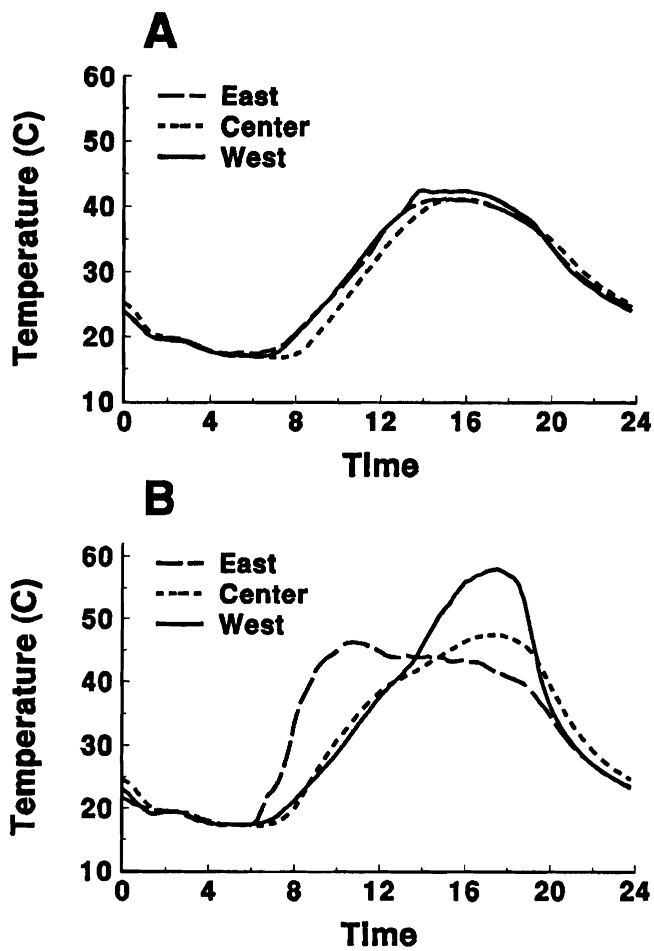

Fig. 1. Diurnal container substrate temperature patterns in the east, center, and west quadrants of containers (A) placed pot-in-pot (PIP) or (B) exposed to sunlight during Summer 1995. Temperatures means were obtained by pooling six replicates of six diurnal measurement dates (June 22–23, July 8–9, and August 9–10, 1995), n = 36. F = [(C)9 / 5 + 32].

Table 1. Effect of above ground container shielding treatments on shoot and root dry weights, shoot-to-root ratio, root length and leaf nitrogen concentration of crape myrtle during Summer 1995.

Shielding treatments[z]	Shoot dry weight (g/plant)	Root dry weight (g/plant)	Shoot-to-root ratio	Root length (m/plant)	Leaf N (%)
PIP	9.9a[y]	3.5a	2.9b	0.39a	2.3b
Exposed	1.9b	0.7b	2.8b	0.08b	2.85a
PIP/Exposed	10.8a	2.6a	4.2a	0.20ab	2.25b

[z]Above-ground container shielding treatments were containers 1) placed pot-in-pot (PIP) for two months, 2) exposed to sunlight for two months, or 3) PIP for one month then exposed to sunlight for one month (PIP/exposed), respectively.

[y]Values are treatment means, n = 4. Mean separation within columns by Duncan's multiple range test, α = 0.05.

cant responses of the variables. Regression coefficients were tested for homogeneity of fit using the F test.

Results and Discussion

Substrates in PIP containers had lower daily maximum temperatures, especially in the west quadrant, and less time each day when temperatures exceeded 40C (104F). The highest mean substrate temperature in PIP containers was 42C (108F) in the west quadrant (Fig. 1A). The number of C-hr above 40C (104F) were 4.7, 1.6, 0.9 in the west, east, and center quadrants, respectively. Temperature patterns in the east, center and west quadrants of the container substrate profile were similar and lacked the distinct bimodal thermal peaks in the late morning and afternoon typical of rooting substrates in containers exposed to sunlight (6). In contrast, the highest mean substrate temperature when containers were exposed to sunlight was 58C (136F) in the west quadrant (Fig. 1B). In addition, the highest mean substrate temperature in the east and center quadrants was 46C (115F) which occurred at 1130 HR and 1600 HR, respectively. The number of C-hr above 40C (104F) were 47.8, 26.8, 19.5 in the west, east, and center quadrants, respectively. In comparison, researchers in Florida reported that the number of C-hr above 40C (104F) for nursery containers exposed to sunlight ranged from 0 to 4.5 (7).

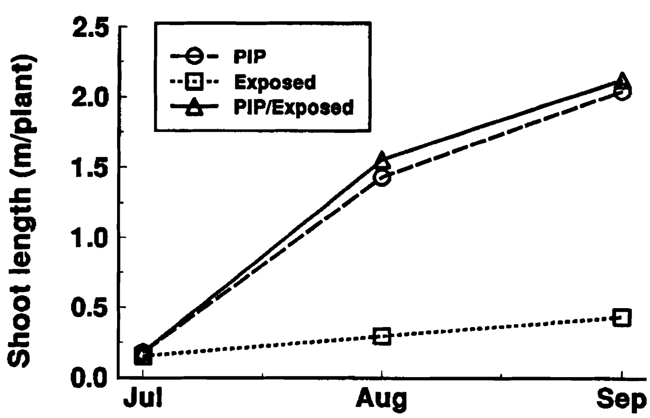

Fig. 2. Crape myrtle shoot length as affected by above-ground container shielding treatments during Summer 1995. Above-ground container shielding treatments were containers 1) placed pot-in-pot (PIP) for two months, 2) exposed to sunlight for two months, or 3) placed PIP for one month then exposed to sunlight for one month (PIP/exposed), respectively.

Shoot and root dry masses of plants in containers exposed to sunlight were less than for those plants in PIP containers or PIP/exposed containers (Table 1). The shoot-to-root ratio of plants in containers exposed to sunlight and of plants in PIP containers were similar, yet both were less than for plants in PIP/exposed containers. These findings contradict an earlier study in which the shoot-to-root ratio was lower for plants in shielded containers compared with those exposed to sunlight (4).

Total shoot length of all plants increased linearly over time ($P = 0.0005$). Furthermore, the linear increase in shoot length of plants in PIP containers and plants in PIP/exposed containers over time was greater than for plants in containers exposed to sunlight ($P = 0.0001$) (Fig. 2). Specifically, shoot length of plants in containers exposed to sunlight after two months was < 0.5 m (19.7 in), while plants in PIP containers or PIP/exposed containers had shoot lengths of about > 2 m (78.7 in). Total root length of plants in PIP containers was greater than for plants in containers exposed to sunlight, but similar to plants in PIP/exposed containers (Table 1); other treatment comparisons for root length were similar.

Leaf nitrogen concentration was highest for plants in containers exposed to sunlight for two months. These results were similar to those reported by others (10, 15) and suggest growth inhibition of heat stressed plants was not related to high substrate temperature impairment of nitrogen uptake. Instead, growth inhibitions may have been related to other processes such as an impaired capacity to synthesize and/or translocate root hormones (16) or increased root respiration for maintenance metabolism (13).

Table 2. Shoot and root dry weights, and shoot-to-root ratio of crape myrtle two months after above ground container shielding treatments.

Shielding treatments[z]	Shoot dry weight (g/plant)	Root dry weight (g/plant)	Shoot-to-root ratio
PIP	33.1a	17.4a	1.90b
Exposed	10.8c	3.1c	3.48a
PIP/Exposed	23.8b	11.6b	2.05b

[z]Above-ground container shielding treatments were containers 1) placed pot-in-pot (PIP) for two months, 2) exposed to sunlight for two months, or 3) PIP for one month then exposed to sunlight for one month (PIP/exposed), respectively.

[y]Values are treatment means obtained by pooling 7 replicates of 4 humic acid extract treatments, n = 28. Mean separation within columns by Duncan's multiple range test, α = 0.05.

Table 3. **Effect of humic acid extract concentration on change in shoot growth and outer root length[z] of crape myrtle following above-ground container shielding treatments[y].**

Humic acid extract concentration (µL/L)	Above-ground container shielding treatments		
	PIP	Exposed	PIP/Exposed
	Change in shoot length (dm/plant)		
0	1.26[x]	0.81	1.87
50	1.96	2.42	0.98
150	1.91	0.79	1.24
300	0.98	1.14	2.00
Significance	Q*[w]	NS	NS
	Outer root length (m/plant)		
0	93.18[x]	19.69	51.03
50	165.84	22.65	43.05
150	55.36	7.17	62.74
300	77.20	13.75	53.64
Significance	Q**[w]	NS	NS

[z]Represents roots which grew beyond the netting into the transplant soil during Summer 1995.

[y]Above-ground container shielding treatments were containers 1) placed pot-in-pot (PIP) for two months, 2) exposed to sunlight for two months, or 3) PIP for one month then exposed to sunlight for one month (PIP/exposed), respectively.

[x]Values are treatment means, n = 7.

[w]Nonsignificant (NS) or significant at the 5% (*) or 1% (**) level; Q = quadratic response.

Two months after transplanting into a landscape substrate, shoot and root dry masses were highest for plants previously in PIP containers, followed by plants previously grown in PIP/exposed containers, and were lowest for containers previously exposed to sunlight (Table 2). The shoot-to-root ratio of plants previously in containers exposed to sunlight was higher than for plants previously grown in PIP containers or PIP/exposed containers (Table 2). These findings suggest that injury to roots in PIP/exposed containers must have occurred when the containers were exposed to sunlight during the second month; however, effects on shoot growth from root injury was not evident until two months after transplanting.

There was a significant interaction between previous shielding treatments and humic acid extract concentrations on the change in shoot length and outer root length (roots that extended outside the netting into the transplant substrate) (Table 3). The change in shoot and root lengths of plants previously in PIP containers both responded in a quadratic fashion to humic acid extract concentrations; the most response occurred at about 50 µL/L while the highest concentrations inhibited post-transplant growth. In contrast, the change in shoot length and outer root length of plants previously in PIP/exposed or exposed containers were not significantly affected by humic acid extract concentrations, possibly because crape myrtle shoot and root growth after high temperature induced root injury were highly variable. Also, humic acid extract concentrations did not affect any other measured variables (data not shown). Experiments with excised pea root segments (14) and tobacco seedlings (11) showed that humic acid affects cell elongation through changes in auxin activity. Thus, humic acid affects on shoot and root growth may not have been related to increased nutrient availability since the humic acid extract used in this experiment contained only minimal amounts of essential plant nutrients.

This study showed that PIP practices can be particularly beneficial to plant growth during nursery production soon after rooted cuttings are placed outdoors in containers. Subsequent exposure to sunlight and supraoptimal rooting substrate temperatures as occurred with plants in PIP/exposed containers, might not be of immediate consequence to plant growth or salability. However, unnoticed root injury caused by supraoptimal root-zone temperatures might become evident at a later date as reduced growth after plants are transplanted into the landscape. Finally, our study suggests that humic acid extract can be useful in landscape management for stimulating post-transplant growth when applied at relatively low concentrations, although it should not be viewed as a biostimulant for heat-stressed roots.

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