

Effect of Fabric and Plastic Containers on Plant Growth and Root Zone Temperatures of Four Tree Species¹

Pamela K. Tauer² and Janet C. Cole³

Department of Horticulture and Landscape Architecture
Oklahoma State University, Stillwater, OK 74078

Abstract

Live oak (*Quercus virginiana* Mill.), red maple (*Acer rubrum* L.), and sweet gum (*Liquidambar styraciflua* L.) trees were planted in #7 fabric or plastic containers on April 18, 2004, and grown for two growing seasons. Live oak and golden rain tree (*Koelreuteria paniculata* Laxm.) trees were planted in #10 fabric or plastic containers on May 6, 2005, and harvested the following summer. Plant height, canopy width, and caliper were measured periodically, and root zone temperatures were recorded at 30-min intervals throughout each study. In the 2004 planting, live oak height and canopy width increased more for plants in plastic containers than for those in fabric containers from May to July 2004. In contrast, no difference in live oak height or canopy width growth occurred between container types from July to September 2004, but trunk caliper increased more in plastic than in fabric containers during this time interval. No differences between container treatments were noted for any measured parameter for red maple or sweet gum trees planted in 2004 or for golden rain tree or live oak trees planted in 2005 at any measurement interval during the study. Average monthly high and low substrate temperatures were similar between the two container types throughout the study. Fabric containers appear to be a reasonable alternative to plastic containers for above ground nursery crop production, although small differences in growth occur for some species.

Index words: alternative production systems, container production, root zone temperature.

Chemicals used in this study: Snapshot 2.5 TG [(trifluralin) (2,6-dinitro-*N,N*-dipropyl-4-(trifluoromethyl)benzenamine) and (isoxaben) (*N*-[3-(1-ethyl-1-methylpropyl)-5-isoxazolyl]-2,6-dimethoxybenzamide)]; Roundup Original (glyphosate) [N-(phosphonomethyl) glycine].

Species used in this study: live oak (*Quercus virginiana* Mill.); red maple (*Acer rubrum* L. 'Autumn Flame'); sweet gum, (*Liquidambar styraciflua* L. 'Cherokee'); golden rain tree (*Koelreuteria paniculata* Laxm.).

Significance to the Nursery Industry

Nursery growers seek better production systems to maintain plant quality and reduce production costs. Fabric containers have been adopted by some nurseries for producing plants in the ground in native field soil as an alternative to baling and burlapping. Some growers are interested in finding alternatives to plastic containers for above ground plant production. This study investigated growth and root zone temperatures of several tree species grown above-ground in fabric and plastic containers. Use of fabric containers for above ground production appears to be a plausible alternative to plastic containers.

Introduction

Nursery growers use various production methods including growing plants in nonwoven fabric containers or plastic containers. Traditionally, nonwoven fabric containers have been used for in-ground production by planting trees in field soil in the fabric container, then placing the fabric container in the ground such that about 5.0 to 7.5 cm (2 to 3 in) of the sidewall extends above the soil surface (15). In contrast, plastic containers have been used for above-ground production or in a pot-in-pot system in which a socket pot is placed

in the ground then the plant is planted in soilless substrate in a second pot, or production pot, that is then placed inside of the socket pot. A disadvantage of the pot-in-pot system is that if the roots grow through the pot drain holes they will also likely grow through the socket pot holes and into the soil making harvest difficult (2). Each production method has advantages and disadvantages. In-ground production in fabric or plastic containers retains a large portion of the root system compared to baling and burlapping (17). An estimated 90% of the root system is outside the harvestable rootball of balled and burlapped plants (6, 16). Gilman and Beeson (8) showed that trees grown directly in field soil or in fabric containers can lose 85% of fine roots but recover quickly with adequate irrigation. The soil surrounding in-ground containers mitigates summer and winter temperature extremes, thus protecting the root system. In-ground production also has the advantage of less plant blow over in windy situations than plants in above ground containers (2).

Despite the advantages of in-ground production, above ground production systems remain viable. Above-ground production allows flexibility in the growing site since native soil characteristics are less of a concern. Traditionally, plastic has been the container of choice for above-ground production, but interest in fabric containers for this production system has increased (15). Fabric containers have been available for over 20 years and have been marketed under several brand names (4). They were developed to reduce harvest costs of field-grown plants and to induce a more fibrous root system (Kurt Reiger, Root Control, Inc., Oklahoma City, OK, personal communication). Fabric containers are available in various sizes, and appropriate container size depends on the trunk caliper at harvest (1).

Plant growth and quality has been variable with fabric containers (15). One reported advantage of the fabric container is

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²Research Specialist.

³Professor. To whom reprint requests should be addressed. janet.cole@okstate.edu

its ability to continually prune roots (10, 11, 12, 14). Smaller roots penetrate the fabric, but as the roots grow, the fabric constricts the root resulting in root pruning (10, 11, 12, 14). Several disadvantages have been noted for fabric containers compared to other production methods. Growers report large costs for time, labor, equipment, and fabric containers before the plants are ready for sale (10, 14). Greater initial costs are incurred for production with fabric containers compared to balling and burlapping or bareroot plant production in the field (10, 14). James (10) also reported that small roots that grow through fabric containers function in water uptake; however, they are removed during harvest, resulting in plants that readily become water stressed. Thus, constant irrigation is needed even for hardened off plants. Many consumers find fabric containers less aesthetically appealing than plastic containers (10, 11, 12, 14).

Chong (3) compared hybrid poplar (*Populus deltoides* × *nigra* DN 69), eastern cottonwood (*Populus deltoides* Bart. Ex Marsh.) and black poplar (*Populus nigra* L.) above ground in fabric containers inserted in progressively larger plastic containers or plastic containers of the same size as fabric containers. Plant height was similar between container types after one year. After two years, the trees in fabric containers had less new canopy growth than those in plastic containers. In another study, no morphological differences occurred between plants grown in the fabric containers compared to those grown in plastic containers (9). Gilman and Beeson (7) found differences in root ball weight and root surface area of several tree species grown in field soil in plastic containers compared to fabric containers. Ingram et al. (9), however, observed that although greater root dry weights of plants grown in fabric containers compared to plastic containers have occurred, the differences were species dependent. Physiological differences were noted in four species grown in plastic or fabric containers (13). Virginia sweetspire (*Itea virginica* L.) died regardless of container type. Common ninebark (*Physocarpus opulifolius* (L.) Maxim) and weigela (*Weigela florida* (Bunge) A. DC.) survived in both containers; however, some branch dieback occurred on common ninebark in plastic containers but not in fabric containers. American cranberry (*Viburnum trilobum* Marsh.) survived and grew well in fabric containers but died in plastic containers.

One disadvantage to growing plants in containers above ground is that plant roots have less protection against temperature extremes. Davidson et al. (5) noted that plants growing in high-density polyethylene containers and exposed to direct solar radiation can have substrate temperatures in the range of 38 to 52°C (100 to 125°F), particularly when the containers are exposed to full sun on the south or west side of production blocks. There has been some speculation that root zone temperatures in fabric containers during the summer may be lower than those of plastic containers. Because fabric containers are porous moisture can readily evaporate through the sides of the container possibly also cooling the root zone region.

The objectives of this study were to characterize 1) plant growth in above-ground production using fabric and plastic containers, and 2) root zone temperatures throughout the growing season in the two container types.

Materials and Methods

2004 Planting. Ten trees each of live oak, red maple and sweet gum were transplanted from #2 plastic containers into

#7 plastic containers [35.6 cm (14 in) top diameter, 28 cm (11 in) bottom diameter, 29.2 cm (11.5 in) deep, Custom™ pots, Nursery Supplies, Inc., Chambersburg, PA], and ten trees from each species were transplanted into fabric containers [35.6 cm (14 in) diameter, 25.4 cm (10 in) deep, Root Control, Inc., Oklahoma City, OK] on April 28, 2004. The substrate consisted of pine bark:peat:sand (3:1:1, by vol) amended per m³ with 7.3 kg (12.3 lb·yd⁻³) of 17N-3P-10K (Osmocote 17-7-12, The Scotts Co., Marysville, OH), 771.3 g (1.3 lb·yd⁻³) Micromax (The Scotts Co.), and 2.3 kg (3.9 lb·yd⁻³) dolomite. The plants were placed on the surface of a Norge loam (fine-silty, mixed, thermic Udic Paleustolls) soil and hand watered to assure that the substrate was moist. Plants were drip irrigated using one 4 mm (0.16 in) internal diameter drip tube per pot attached to a drip emitter (Rain bird, Azusa, CA) installed in an 18 mm (0.6 in) internal diameter feeder line. Emitters provided 3.8 liters (1 gal) of water hourly and were controlled with a time clock set to run for 4 hr per day during the growing season. Plants were irrigated as needed during the dormant season. Weed control within the containers was with Snapshot (Dow AgroSciences, Indianapolis, IN) applied on May 18, 2004, at 112 kg·ha⁻¹ (100 lb·A⁻¹) and by hand weeding. Weed control around the containers was with spot applications as needed of glyphosate (Monsanto, St. Louis, MO) applied at 7.2 g ai·liter⁻¹ (1 oz ai·gal⁻¹) or by hand weeding.

Tree height, caliper (trunk diameter) at 2.5 cm (1 in) above the substrate, and canopy width (average of width at the widest portion and perpendicular to the widest portion) were determined on the following dates: May 2, July 22, and September 15, 2004, and July 29 and September 29, 2005. Growth between measurement dates for each parameter measured was calculated as $G = T_2 - T_1$ where G = growth, T_2 = measurement (height, canopy width, or caliper) at the end of the growth interval, and T_1 = measurement of the same parameter at the beginning of the growth interval. After the September 29, 2005, measurements, one-half of the red maple and sweet gum trees in each container treatment were harvested. Roots were washed and graded into three size classifications: a) roots less than 1 mm (0.04 in) in diameter, b) roots between 1 mm (0.04 in) and 5 mm (0.2 in) in diameter, and c) roots greater than 5 mm (0.2 in) in diameter. The roots were dried in a drying oven at 70°C for five days and weighed.

Root zone temperatures were measured at half hour intervals throughout the study using soil temperature sensors and dataloggers (Watchdog model 400 and 425, Spectrum Technologies, Plainfield, IL) installed in five containers for each species and container type. Soil temperature sensors were placed in the middle of the substrate (centered between the top and bottom and sides) in the containers at planting. From these data, daily high and low soil temperatures were determined and monthly average high and low temperatures were calculated.

2005 Planting. The experiment was repeated as described above with the following exceptions, live oak and golden rain tree were the species tested. Plants were planted in #10 plastic containers [40.6 cm (16 in) top diameter, 33.7 cm (13.25 in) bottom diameter, 38.1 cm (15 in) deep] and fabric containers [41.9 cm (16.5 in) diameter and 36.2 cm (14.25 in) deep] on May 6, 2005. Height, canopy width, and trunk caliper were measured May 6, July 26, and October 13, 2005. Plants were

Table 1. Increase between measurement dates during 2004 and 2005 in height, canopy width, and trunk caliper at 2.5 cm (1 in) above the substrate surface of sweet gum, red maple, and live oak grown in #7 plastic or fabric containers. n = 10.

Container type	Size increase \pm 95% confidence interval		
	Height (cm)	Canopy width (cm)	Trunk caliper (mm)
<i>Sweet gum, May 2, 2004 to July 22, 2004</i>			
Fabric	59.8 \pm 8.4	77.0 \pm 8.5	15.9 \pm 1.2
Plastic	50.3 \pm 7.6	83.3 \pm 10.3	18.3 \pm 1.1
<i>Sweet gum, July 22, 2004 to September 15, 2004</i>			
Fabric	34.6 \pm 12.6	3.2 \pm 5.6	12.9 \pm 1.2
Plastic	42.2 \pm 16.7	6.8 \pm 10.3	12.4 \pm 1.7
<i>Sweet gum, September 15, 2004 to July 29, 2005</i>			
Fabric	67.2 \pm 11.5	29.7 \pm 7.2	14.0 \pm 2.0
Plastic	62.7 \pm 5.8	26.2 \pm 6.3	13.7 \pm 1.3
<i>Sweet gum, July 29, 2005 to September 29, 2005</i>			
Fabric	1.9 \pm 3.6	0.7 \pm 10.9	4.3 \pm 1.7
Plastic	1.6 \pm 2.9	1.6 \pm 1.4	4.2 \pm 1.1
<i>Red maple, May 2, 2004 to July 22, 2004</i>			
Fabric	63.4 \pm 11.7	50.2 \pm 12.6	12.6 \pm 1.0
Plastic	81.4 \pm 8.3	56.9 \pm 8.0	13.9 \pm 1.3
<i>Red maple, July 22, 2004 to September 15, 2004</i>			
Fabric	24.9 \pm 7.1	18.8 \pm 7.6	8.8 \pm 1.0
Plastic	25.7 \pm 5.9	7.4 \pm 5.0	7.9 \pm 1.2
<i>Red maple, September 15, 2004 to July 29, 2005</i>			
Fabric	40.7 \pm 7.0	41.4 \pm 11.2	12.4 \pm 1.9
Plastic	32.9 \pm 8.9	55.4 \pm 9.6	12.3 \pm 2.1
<i>Red maple, July 29, 2005 to September 29, 2005</i>			
Fabric	0.7 \pm 1.3	0.1 \pm 11.0	1.0 \pm 1.7
Plastic	1.2 \pm 1.0	1.2 \pm 0.5	1.5 \pm 1.8
<i>Live oak, May 2, 2004 to July 22, 2004</i>			
Fabric	13.3 \pm 7.7	18.4 \pm 9.4	4.4 \pm 1.5
Plastic	38.1 \pm 7.8	43.8 \pm 6.6	6.3 \pm 0.6
<i>Live oak, July 22, 2004 to September 15, 2004</i>			
Fabric	15.4 \pm 9.0	27.4 \pm 10.1	3.2 \pm 1.7
Plastic	18.0 \pm 7.7	45.5 \pm 7.6	8.2 \pm 0.8

harvested after one growing season, and data on root size were not collected at harvest.

Statistics. The plants were grouped on the irrigation bed by species and container type to allow needed irrigation flexibility. Means and 95% confidence intervals of the mean (CI) were calculated for each treatment. Overlapping CI indicated that the treatments produced a similar result. Mean monthly minimum and maximum container substrate temperatures were calculated along with their standard deviations.

Results and Discussion

2004 Planting. Increases in height, canopy width, and trunk caliper were similar between container types for sweet gum and red maple during all measurement intervals (Table 1). The weight of small, medium, and large roots and total root weight at harvest did not differ between container types for sweet gum or red maple (Table 2).

Live oaks in plastic containers grew more in height and width from May 2, 2004, to July 22, 2004, than those in fabric containers, but no difference in trunk caliper growth

Table 2. Weight of small (<1 mm, 0.04 in diameter), medium (1 mm, 0.04 in to 5 mm, 0.2 in diameter), large (>5 mm, 0.2 in diameter) roots and total root weight of sweet gum and red maple trees grown in #7 fabric or plastic containers. n = 5.

Container type	Root weight (g) \pm 95% confidence interval			
	Small	Medium	Large	Total
<i>Sweet gum</i>				
Fabric	161 \pm 65	289 \pm 45	1,262 \pm 106	1,713 \pm 136
Plastic	125 \pm 53	296 \pm 152	1,253 \pm 175	1,674 \pm 348
<i>Red maple</i>				
Fabric	332 \pm 59	329 \pm 121	886 \pm 182	1,548 \pm 128
Plastic	308 \pm 177	270 \pm 26	902 \pm 102	1,480 \pm 201

occurred among container types during this time (Table 1). From July 22, 2004, to September 15, 2004, growth in height and canopy width did not differ between container types, but trunk caliper increased more for live oak trees in plastic containers than for those in fabric containers. Tops of several live oaks died during the winter. When measurements were taken on July 26, 2005, two were dead in plastic containers and four were dead in the fabric containers. By September 29, 2005, one additional live oak tree had died in the plastic containers.

2005 Planting. No difference between container types occurred for increase in height, canopy width or caliper of golden rain tree or live oak for any measurement interval (Table 3). Substrate temperature did not differ between plastic and fabric containers at any time during 2004 or 2005 (Table 4).

Plants were purposely left in the containers until they were larger than the recommended harvest size for the containers (1). At harvest, no difference in distribution between small, medium or large roots was detected (Table 2), but different root architecture was observed on plants in plastic containers compared to plants in fabric containers. Plants in plastic containers had more apparent root circling than those in fabric containers. Roots of plants in fabric containers ap-

Table 3. Increase between measurement dates during 2005 in height, canopy width, and trunk caliper at 2.5 cm (1 in) above the substrate surface of golden rain tree and live oak grown in #10 plastic or fabric containers. n = 10.

Container type	Size increase \pm 95% confidence interval		
	Height (cm)	Canopy width (cm)	Trunk caliper (mm)
<i>Golden rain tree, May 6 2005 to July 26, 2005</i>			
Fabric	17.2 \pm 7.6	8.4 \pm 12.8	9.2 \pm 1.6
Plastic	23.7 \pm 8.1	9.0 \pm 7.4	8.0 \pm 1.3
<i>Golden rain tree, July 26, 2005 to October 13, 2005</i>			
Fabric	0.4 \pm 0.5	24.2 \pm 11.6	4.6 \pm 1.3
Plastic	0.3 \pm 0.7	27.1 \pm 9.3	5.7 \pm 1.3
<i>Live oak, May 6, 2005 to July 26, 2005</i>			
Fabric	27.3 \pm 10.1	41.1 \pm 16.6	5.7 \pm 1.0
Plastic	17.2 \pm 5.3	32.0 \pm 8.8	5.3 \pm 1.6
<i>Live oak, July 26, 2005 to October 13, 2005</i>			
Fabric	20.5 \pm 9.6	53.1 \pm 14.9	11.5 \pm 1.3
Plastic	27.7 \pm 13.6	50.4 \pm 10.0	14.2 \pm 1.5

Table 4. Monthly average high and low substrate temperatures in fabric or plastic containers.

Year	Month	Container type	Average temperature (C) \pm S.D. ^z	
			High	Low
2004	May	Fabric	30.3 \pm 2.4	21.7 \pm 1.9
		Plastic	32.0 \pm 2.0	22.5 \pm 2.3
	June	Fabric	29.8 \pm 3.1	21.3 \pm 2.9
		Plastic	30.9 \pm 2.9	21.8 \pm 2.4
	July	Fabric	31.6 \pm 4.3	22.6 \pm 2.8
		Plastic	32.8 \pm 4.2	22.8 \pm 5.3
	August	Fabric	29.4 \pm 4.4	20.9 \pm 3.4
		Plastic	31.5 \pm 9.3	21.4 \pm 3.6
	September	Fabric	28.3 \pm 2.3	18.6 \pm 6.6
		Plastic	29.4 \pm 3.1	18.9 \pm 3.4
	October	Fabric	20.4 \pm 3.4	13.7 \pm 3.4
		Plastic	21.7 \pm 7.4	14.6 \pm 5.7
2005	January	Fabric	11.1 \pm 3.6	6.8 \pm 3.9
		Plastic	11.8 \pm 4.1	6.7 \pm 4.3
	December	Fabric	— ^y	— ^y
		Plastic	— ^y	— ^y
	January	Fabric	3.6 \pm 5.2	0.2 \pm 3.7
		Plastic	4.2 \pm 6.1	0.1 \pm 4.4
	February	Fabric	8.7 \pm 4.3	3.5 \pm 3.2
		Plastic	10.6 \pm 4.7	3.4 \pm 3.8
	March	Fabric	14.6 \pm 4.4	6.5 \pm 3.1
		Plastic	13.9 \pm 8.9	4.1 \pm 7.1
	April	Fabric	19.4 \pm 3.3	11.9 \pm 4.0
		Plastic	22.7 \pm 4.1	12.2 \pm 3.9
	May	Fabric	24.4 \pm 5.7	17.2 \pm 8.1
		Plastic	26.0 \pm 5.9	15.8 \pm 7.8
	June	Fabric	28.6 \pm 2.6	22.3 \pm 3.9
		Plastic	31.6 \pm 3.6	22.1 \pm 3.1
	July	Fabric	33.6 \pm 2.2	24.7 \pm 2.2
		Plastic	35.3 \pm 2.8	25.5 \pm 2.8
	August	Fabric	32.3 \pm 7.6	24.3 \pm 1.9
		Plastic	33.8 \pm 4.6	24.1 \pm 4.1
	September	Fabric	32.7 \pm 5.7	21.2 \pm 3.4
		Plastic	31.9 \pm 4.9	21.6 \pm 4.1
	October	Fabric	22.7 \pm 5.5	13.9 \pm 5.2
		Plastic	22.4 \pm 5.8	13.0 \pm 5.3

^zS.D. = Standard deviation.

^yDaily high and low temperatures were not available for December 2004 due to datalogger malfunction.

peared much more branched and fibrous than roots in plastic containers just inside the container wall. The significance of these observations relative to future plant performance was not determined. James (10) noted that small roots grow through the bottom of fabric containers into the soil below. Roots also grow through the drainage holes of plastic containers if given the opportunity. Growth of roots into the soil below containers can be reduced by placing the containers on weed barrier fabric or other materials with limited root permeability.

No differences were observed in average daily substrate temperature between container types for any month during the study (Table 4). Root zone temperatures were measured in the center of each root ball, but temperatures were not measured at the interface between the roots and the container

walls. While there were no differences in monthly high or low temperature between container types noted at the center, it is possible that temperatures at the rootball-container interface were different. Neal (13) measured temperatures 1 in (2.5 cm) from the container wall on the south-southwest side of the container and found temperatures at this location in plastic containers to be as much as 14 to 17C (25 to 30F) higher than in fabric containers. Fabric containers are more porous, which might allow evaporative cooling to dissipate heat more readily than nonporous plastic containers.

Few differences in height, canopy width, or trunk caliper occurred between container types for any of the species tested in this study at any measurement interval. Less root circling was observed in sweet gum and red maple trees in fabric containers compared to those in plastic containers. Fabric containers appear to be a viable alternative to plastic containers for above-ground plant production.

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