Container Grown Plant Production

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Section Editor

Effects of Container Color on Root Zone Temperature and Growth of 'Green Giant' Arborvitae

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Significance to the Industry Supraoptimal root zone temperatures continue to negatively impact container production of sensitive crops through root damage, reduction in growth rates and increased disease susceptibility. Arborvitae is known to be sensitive to extreme heat in container production. This study evaluated arborvitae growth and substrate temperature in different types of containers and two container substrates. Plants grown in white containers with a 100% pine bark (PB) substrate were 10% larger (growth index) compared with plants in black pots using the same substrate. White pots using a mix of 4 pine bark:1 peatmoss (PB:PM) substrate produced plants 20 and 21 % larger than black pots using PB based on growth index and shoot fresh weight, respectively. Root zone temperatures for black containers were over 40°C 10.2 (PB) and 9.1% (PB:PM) more of the time compared to white containers. This research demonstrated increased plant growth and reduced substrate temperatures could be achieved in arborvitae plants grown in white containers compared with black containers.

Nature of Work The negative effects of root zone temperature (RZT) in container production have been observed since the early days of commercial container nursery production where metal cans filled with field soil blends were used (9). Supraoptimal RZT often exceeds that of air temperatures due to container walls absorbing solar radiation which is converted to heat and retained in container substrates. Factors such as substrate component, substrate porosity, and moisture level affect the rate at which heat energy is lost and can lead to significantly greater RZT over long periods compared to ambient air temperatures (6). Container color and porosity also have an effect on the rate of solar absorption and heat dissipation. Dark colored containers (predominantly black) absorb more heat compared to white containers and solid wall plastic containers maintain higher temperatures than more porous materials such as peat and fabric containers (7). In a study conducted in Manhattan, KS, Markham et al. (5) observed maximum temperatures of 55.2°C (131.4 °F) in black one gallon nursery containers. The point at which RZT becomes damaging or lethal is a function of not only temperature but also temperature duration, crop species, and plant conditioning (8, 10). Research has shown that reduced RZT and improved plant growth can be achieved through the use of container spacing, white containers, shading containers and porous container materials compared to conventional black containers (1,2,4,5). Ingram et al. (3), in an extensive review of research involving the impacts of supraoptimal RZT in container grown plants, summarized RZT between 38 and 40°C (100.4 and 104 °F) hampered physiological processes and that short exposures between 46 and 52°C (114.8 and 125.6 °F) damaged cell membranes. The review concluded that work directed toward reducing RZT in container production should target reduction below these levels. The objective of this study was to evaluate and demonstrate the effects of container color, container type and substrate on growth of 'Green Giant' arborvitae (*Thuja standishii* x *plicata* 'Green Giant').

Three different containers and two substrates were evaluated in this study. Containers included black and white 11.3 L (3 gal) solid wall containers (Nursery Supplies Inc., Kissimmee, FL) and a 10.5 L (5 gal) air pruning container (Rediroot) (Nursery Source Inc., Boring, OR). Two substrates were evaluated in combination with each container (six total treatments) and included 100% pine bark (PB) and a mix of 4 pine bark : 1 peatmoss (v:v) (PB:PM). On April 19, 2017, trade gallon 'Green Giant' arborvitae were transplanted into each treatment with 12 replicates per treatment. Plants were arranged in a randomized complete block design. To provide maximum surface area to sunlight, plants were spaced on 0.91m (3 ft) centers.

Separate irrigation zones were used for each treatment to monitor and adjust irrigation application rates. Water was delivered to each plant with a dribble ring (15 cm (5.9 in) diameter; Dramm Corp., Manitowoc, WI) fitted with a pressure compensated emitter (8 lph; Netafim USA, Fresno, CA). Decagon 5TE sensors and EM50 data loggers (Decagon Devices Inc., Pullman, WA) were used to measure and collect substrate temperature, volumetric water content and electrical conductivity (EC). Sensors were positioned vertically approximately 4.5 cm (1.7 in) from the container sidewall and placed below the substrate surface extending 11 cm (4.3 in). The study was terminated 166 days after planting (DAP; October 3, 2017) and plants were destructively harvested. Plant height and diameter were measured (0, 59, 138, and 166 DAP) and growth index (GI) was calculated [(height+width1+width2)/3]. Shoot dry weight (n=12) and root dry weight (n=4) were measured after being oven dried at 70°C (158^{o} F) for approximately 7 days. Substrate pH and EC were monitored using the Virginia Tech Pour-through Method at 52, 97, 146 and 166 DAP. The percentage of time roots were exposed to temperatures above the critical thresholds (38, 40 and 46^{o} C (100.4, 104.0 and 114.8^{o} F) mentioned by Ingram et al. (3) was calculated using the total number of data recordings for each day between 6 am and 8 pm. Irrigation application volume for each treatment was adjusted throughout the study based on a target leaching fraction of 10 - 20%.

All data were analyzed with linear models using the GLIMMIX procedure of SAS (Version 9.3; SAS Institute, Inc., Cary, NC). Differences between treatment means were determined using the Shaffer-Simulated method ($P < 0.05$).

Results and Discussion No differences were observed among treatments for pH or EC throughout the study (Table 1). Across all treatments, no differences were observed in shoot dry weight; however, plants grown in white containers were 10% larger than those in black containers based on final GI when comparing containers with the same substrate

(Table 2, 3). Plants grown in white containers using an PB:PM mix were 20 and 21 % larger than plants in black containers using PB for GI and shoot fresh weight, respectively. Final GI was similar for plants in black and Rediroot containers within PB and within PB:PM. Markham et al (5) also observed an increase in growth when comparing black and white containers. Plants grown in PB:PM had significantly greater shoot fresh weight compared with PB within the same container type but there was no effect on GI. Nevertheless, differences in final GI between PB and PB:PM were 8, 15 and 35% for black, white and air pruning containers, respectively. This increase in growth could be explained by the greater substrate moisture holding capacity of PB:PM compared to PB (data not reported). The method in which irrigation duration was adjusted may have negatively influenced growth in the Rediroot containers. Air pruning containers often require higher frequency irrigation applications to maintain critical moisture levels due to evaporative loss from pot sidewalls.

Root zone temperature (Table 4) above 40°C was significantly greater for both substrates in black containers compared with all other treatments, remaining above 40°C at least 8.3% more of the time. Root zone temperatures for PB and PB:PM in black containers were above 38°C for 11 to 28.9% more of the time compared with the remaining treatments. Root zone temperature did not reach above 46°C in white or Rediroot containers (either substrate). In our study, substrate type (within container type) did not affect the percent of time temperatures were above the reported critical values. Martin and Ingram (6) suggested that as substrate porosity decreased an increase in the lateral movement of water would occur resulting in reduced RZT, but differences in porosity may not have been great enough between substrates in the present study to achieve such effects. Substrate volumetric water content data for the present study will be analyzed and be used to further interpret results of this study.

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Table 1. Effects of container and substrate type on pH and electrical conductivity of container leachates.

		pH (DAP[z])				EC (µmho/cm) (DAP)			
Container	Substrate	52	97	146	166	52	97	146	166
Black	PB[x]	7 a[y]	6 a	6 a	7 a	303 a	549 a	212 a	640 a
Black	PB:PM[w]	7 a	6 a	6 a	6 a	294 a	485 a	231 a	703 a
White	PB	6 a	6 a	6 a	6 a	529 a	447 a	137 a	339 a
White	PB:PM	7 a	6 a	6 a	6 a	328 a	261 a	156 a	238 a
Rediroot	PB	7 a	6 a	5 a	6 a	516 a	497 a	161 a	426 a
Rediroot	PB:PM	7 a	6 a	6 a	6 a	450 a	420 a	159 a	236 a

[z]Days after planting.

[y]Data were analyzed with linear models using the GLIMMIX procedure of SAS (Version 9.3; SAS Institute, Inc., Cary, NC). Means followed by different letters within columns indicate significant difference at $P < 0.05$ using the Shaffer-Simulated method.

[x]100% pine bark substrate.

[w]4 pine bark : 1 peatmoss substrate (v:v).

Table 2. Effects of container type and substrate on plant growth of *Thuja standishii* x *plicata* 'Green Giant' grown for 166 days.

		Growth Index[z]				Height (cm)			
Container	Substrate	0[y]	59	138	166	0	59	138	166
Black	PB[w]	42.3 a[x]	51.3 a	54.4 c	55.1 dc	61.5 a	68.7 a	71.4 d	72 b
Black	PB:PM[v]	41.1 a	53.4 a	58.5 b	58.8 bc	60.8 a	70.0 a	76.7 dc	78 b
White	PB	40.5 a	52.3 a	59.6 ba	61.5 ba	62.3 a	70.9 a	75.9 dc	76 b
White	PB:PM	41.4 a	53.7 a	62.8 a	65.1 a	61.9 a	73.3 a	80.5 bc	81 b
Rediroot	PB	40.2 a	50.2 a	50.1 d	52.2 dc	62.1 a	73.9 a	88.3 ba	91 a
Rediroot	PB:PM	42.6 a	53.3 a	56.2 bc	58.1 bc	60.6 a	71.8 a	90.3 a	95 a

[z]Growth index = (height+width1+width2)/3.

[y]Days after planting.

[x]Data were analyzed with linear models using the GLIMMIX procedure of SAS (Version 9.3; SAS Institute, Inc., Cary, NC). Means followed by different letters within columns indicate significant difference at $P < 0.05$ using the Shaffer-Simulated method.

[w]100% pine bark substrate.

[v]4 pine bark : 1 peatmoss substrate (v:v).

Table 3. Effects of container and substrate on shoot and root biomass of *Thuja standishii* x *plicata* 'Green Giant' grown for 166 days.

Container	Substrate	Shoot Fresh Weight (g)	Shoot Dry Weight (g)	Root Dry Weight (g)
Black	PB [y]	401.7 c[z]	162.0 a	508.5 a
Black	PB:PM[x]	477.2 ba	195.2 a	504.5 a
White	PB	435.7 bc	169.7 a	506.5 a
White	PB:PM	511.3 a	200.7 a	614.0 a
Rediroot	PB	302.7 d	120.3 b	494.0 a
Rediroot	PB:PM	462.2 ba	185.5 a	574.0 a

[z]Data were analyzed with linear models using the GLIMMIX procedure of SAS (Version 9.3; SAS Institute, Inc., Cary, NC). Means followed by different letters within columns indicate significant difference at $P < 0.05$ using the Shaffer-Simulated method.

[y]100% pine bark substrate.

[x]4 pine bark : 1 peatmoss substrate (v:v).

Table 4. Percentage of time substrate temperatures remained over damaging temperatures (38, 40, and 46°C).

Container	Substrate	38°C	40°C	46°C
Black	PB [y]	33.6 a[z]	13 a	2.2 a
Black	PB:PM [x]	18.1 ab	11 a	1.1 ab
White	PB	7.1 b	2.7 b	0.0 b
White	PB:PM	6.1 b	2.1 b	0.0 b
Rediroot	PB	4.7 b	1.7 b	0.0 b
Rediroot	PB:PM	6.6 b	2.9 b	0.0 b

[z]Data were analyzed with linear models using the GLIMMIX procedure of SAS (Version 9.3; SAS Institute, Inc., Cary, NC). Means followed by different letters within columns indicate significant difference at $P < 0.05$ using the Shaffer-Simulated method.

[y]100% pine bark substrate.

[x]4 pine bark : 1 peatmoss substrate (v:v).

Academic and Economic Benefits Accrued from Integration of Nursery Production and Propagation Learning Experiences within a Multidisciplinary Low Impact Development (LID) Landscape Project

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Index Words Interdisciplinary research, sustainable landscape design, rain garden, container nursery production, bioretention

Significance to Industry Integration of nursery production and propagation learning experiences into multidisciplinary low impact development (LID) landscape research project improves students' knowledge of both sustainable landscape practices and assists in their exposure to the production side of the Green Industry. This will hopefully result in a greater awareness of career opportunities in nursery production and landscape architecture fields.

Nature of Work With expanding urbanization continuing unabated, enhancing sustainability of the built environment using improved landscape design strategies, such as LID, are of increasing importance in minimizing runoff and non-point source pollution from impervious land cover. This innovative approach to treating stormwater prior to discharge uses stormwater collection devices, water reuse mechanisms, and biofiltration systems to limit adverse impacts of runoff. The current project "Aggie B.L.U.E. print Laboratories: **B**uilding **L**asting **U**niversity **E**nvironments" incorporates LID strategies in the development of a rain garden which is to be incorporated into the new Texas A&M University Gardens and Greenway (1, 2). As a planned component of this multi-disciplinary teaching and research opportunity students from three departments in three different colleges are involved in the planning, design, production of plants, collection and analysis of runoff data, installation, and monitoring of the project. Students growing the plants in greenhouses and a container nursery for incorporation in the rain garden are a major horticultural component of the overall project. In the following paragraphs the overall outcomes of the process and an estimate of economic contributions from the student oriented production of plants is outlined.

Results and Discussion To date over 300 students from a dozen different courses in the Department of Landscape Architecture and Urban Planning, Department of Horticultural Sciences, and Department of Civil Engineering and five faculty members have been directly involved in the project. In addition, enthusiastic assistance has been provided from the TAMU Gardens and Greenway and SSC corporation staff (firm to which campus grounds maintenance has been outsourced) laying a solid framework for future cooperative educational, research and outreach efforts.

A decline in the number of horticulture majors has been recognized as a recent national trend (3) and activities exposing students to horticulture production may serve as an entree into the industry. The horticultural components of this project were specifically formulated to facilitate not only landscape design and installation activities, but to also facilitate exposure to and experiences with hands-on propagation and production of the plants to be used in the design. Students learned many technical aspects of propagating and growing dozens of different taxa for the project (Figure 1). Most plants were propagated from seeds or cuttings, with a few purchased as small plugs or liners and then grown on to sizes ranging from 4 inch quart pots to 100 gallon trees. Students gained experiences with essentially the entire gamut of nursery production activities from rooting cuttings and germinating seeds, to choosing substrates, fertilization schedules, monitoring pest and disease outbreaks, pruning, training and perhaps most importantly time and staging of a variety of crops to mature simultaneously. Repeated delays due to access limiting construction on adjacent sites provided students (and faculty) with real-world experiences in improvisation of project implementation and nursery production schedules.

In addition to the academic benefits to student participants, growing plants internal to the university accrued economic benefits through cost savings. Using a replacement value method to estimate the contributions of plants produced by the students for the project, a conservative wholesale value estimate of the plants produced was $26,258.00 (Table 1). Retail prices are often double those of wholesale prices and the wholesale prices estimated here were FOB from nursery website inventories and thus did not include shipping costs. Most of the shipping costs are saved with internal production onsite. Shipping costs are often an additional ten to twenty percent of the cost of goods sold. Wholesale delivered costs would easily be in excess of $30,000 and if plants were purchased retail, probably represent a $50,000 to $60,000 value returned to offset implementation costs of the project. Funding sources included the TAMU Tier One Program, Aggie Green Fund, and facilities funded in part by hatch funds from NIFA.

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Table 1. Estimated value of container grown taxa based on wholesale prices, not including shipping costs, posted on grower websites in November 2017. Plants were grown from seeds, cuttings, or plug liners by students involved in a multidisciplinary team studying a LID rain garden project.

Taxa	Size	Representative wholesale price $/Unit	Quantity	Wholesale Total value ($)
Andropogon glomeratus	#5	9.50	75	712.50
Aster pilosus	#3	8.50	38	323.00
Baptisia spp.	4”	2.00	320	640.00
Bouteloua curtipendula	#2	7.50	300	2,250.00
Canna x *generalis* ‘Bengal Tiger’	#10	18.00	50	900.00
Canna x *generalis* ‘Tropicana’	#10	18.00	50	900.00
Cephalanthus occidentalis	#25	75.00	10	750.00
Chasmanthium latifolium	#3	7.50	188	1,410.00
Erygium yuccifolium	#1	3.00	80	240.00
Eupatorium coelestinum	#3	8.50	90	765.00
Eupatorium greggii	#3	8.50	180	1,530.00
Eupatorium purpureum	#5	9.50	135	1,252.50
Eysenhardtia texana	#15	55.00	10	550.00
Helianthus angustifolius	#5	9.50	106	1,007.00
Helianthus maxmilliani	#2	7.50	46	345.00
Iris virginiana	#2	7.50	70	525.00
Juncus pallidus ‘Javelin’	#2	8.50	104	884.00
Leucophyllum frutescens	#1	3.00	14	42.00
Malvaviscus arboreus	#5	9.50	50	475.00
Phyla nodiflora	#4	1.50	475	712.50
Phylostachys aureosuculenta	#15	150.00	10	1,500.00
Phylostachys nigra	#15	120.00	10	1,200.00
Raphiolepis umbellata	#5	12.00	2	24.00
Rosmarinus officinalis	#3	9.50	10	95.00
Sabal minor	#1	5.00	18	90.00
Salvia uliginosa	#3	8.50	108	918.00
Semiarundinaria fastuosa	#15	65.00	10	650.00
Solidago gigantea	#2	7.50	60	450.00
Solidago speciosa	#2	7.50	54	405.00
Tagetes lemmonii	#3	9.50	210	1,995.00
Taxodium distichum	#100	450.00	1	450.00
Tradescantia ohiensis	4”	2.00	20	40.00
Tradescantia ohiensis	#2	7.50	45	337.50
Zephranthes spp.	#1	3.00	630	1,890.00
Total			3579	26,258.00

Figure 1. Overview of plants grown for the project in the nursery at the new Horticulture Research, Teaching, and Extension Center (HortTREC) in College Station, Texas.