Retractable Roof Greenhouse (RRG) Versus Bareroot Tree Liner Post Harvest Survival and Growth in Nursery Production©

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Since 2002 at Ohio State University (OSU), Columbus, Ohio, trials in containerized tree liner production have indicated acceleration of production times in pot-in-pot (PIP) and field tree systems, increased crop consistency via reduced mortalities and environmental affects and new market expansion to include higher priced, difficult-to-grow species can be obtained over conventional nursery practices. The production systems researched at OSU is conducted in retractable roof greenhouses (RRGs) (Cravo Equipment, Ltd., Brantford, Ontario, Canada). In 2004, #3 (trade 3-gal) (11.4 L) containerized tree liners from RRGs had 0% mortality versus field bareroot production *Quercus rubra* at 42% after out-planting into nursery fields to grow on as specimen trees. Averaged over species, RRG liners reached saleable size (50 mm) 2-in. caliper 2 years sooner than the bareroot liners, or a 40% reduction in production time. In 2006, #3 containerized tree liners from RRGs had 27% mortality versus field bareroot production at 87% after out-planting to #7 (trade 7-gal) (26.5-L) containers and harsh (March 2006, Avon, Ohio) conditions in PIP fields. Averaged over species and one growing season, caliper (18.9 mm) and height (166.43 cm) of RRG liners were significantly larger than bareroot liners (3.6 mm and 26 cm) or 82% and 84% larger, respectively. In only 4 months, between 1 May and 30 Aug. 2007, heights and calipers of 5 ft 8 in. (178 cm) and 0.39 in. (9.9 mm) *Cercis canadensis* (Eastern red bud); 4 ft 8 in. (146 cm) and 0.38 in. (9.7 mm) *Tilia cordata* 'Greenspire' (greenspire linden); and 3 ft 8 in. (118.4 cm) and 0.29 in. (7.4 mm) *Acer* × *freemanii* 'Jeffersred' (Autumn Blaze™ red maple) liners were produced at OSU, Columbus, Ohio, supporting our hypothesis that RRG liners can be double-cropped to accelerate production further. We are currently working with 0.4-in. liners that are double-cropped out of RRGs to produce 2-inch caliper #25 PIP container trees in 2 years or a 67% reduction in production time versus conventional nursery practices.

INTRODUCTION

A tree liner refers to a small plant that is transplanted and grown on to become a larger plant. Tree liners are typically produced in the Pacific Northwest nursery fields and sold bareroot to be grown in Midwestern and Eastern Seaboard U.S.A. to become caliper trees. Caliper trees are also called specimen trees and derive their name from the instrument that is used to measure their diameter, i.e., calipers. Pot-in-pot (PIP) consists of a planted container, placed in a holder pot that has been permanently placed in the ground. With PIP versus conventional field production approximately three times the number of plants per unit area of land can be produced, plants are harvested in a shorter period of time, greater mechanization potential exists, labor and equipment needs in terms of digging are reduced, and plants can be harvested year-round (Mathers, 2002). Retractable roof greenhouses (RRGs) can be flat-roof or peak-roof curtain houses. Peaked-roof houses are being used in colder climates because the A-frame roof when closed can stand up to heavy snow loads. However, flat-roof houses cost approximately a third of peak-roof houses to construct (Mathers, 2001). The retractable roof design allows 90% roof retraction, and has roll-up end walls and sidewalls. Retractable roof greenhouses researched at Ohio State University (OSU) have been found to increase plant water use efficiency (WUE) and nitrogen use efficiency (Stoven et al., 2005), increase growth (Mathers et al. 2006; Stoven et al., 2005), cut production times of certain crops in half (Mathers, 2001), reduce wind throw problems, and extend growing seasons (Stoven et al., 2005). For some growers the costs of PIP and RRGs have made their use prohibitive. Current PIP systems that have been installed in Ohio are running $30–32,000 per acre and RRG installations $250,000 per acre (peaked-roof). Accelerating and increasing productivity of PIP and RRG installations would make their use more affordable and equitable. To this end the three studies listed below were evaluated at OSU, Columbus, Ohio.

MATERIALS AND METHODS

Optimum Environment and Species for Containerized Tree Liner Production. Five species of trees were selected after discussions with Ohio growers to determine which traditionally difficult-to-grow species had the greatest niche market potential in Midwest shade-tree production. Niche market for this study included species that were coarse-rooted, difficult-to-transplant, and/or native taxa. Three environments were tested: peaked-RRG, flat-RRG, and a Rutgers'-style polyhouse at OSU, Columbus, Ohio. If the polyhouse or flat-RRG provided similar growth and quality liners to the peaked-RRG, then Midwest liner production could be more attractive to a larger audience of nursery producers due to lower start-up and construction costs. The five species selected for the study were yellowwood, (*Cladrastis kentukea*), a difficult to acclimate native species; red oak (*Quercus rubra*), coarse rooted and in previous studies requiring at least 2 years to reach marketable size; stewartia (*Stewartia pseudocamellia*), a species prone to root rot diseases; Japanese tree lilac (*Syringa reticulata* 'Ivory Silk') and littleleaf linden (*Tilia cordata* 'Greenspire') two species in short supply as bareroot liners.

The trial was repeated over 2 years, 2005 and 2006, so that environment could be replicated. Seedlings of yellowwood, red oak, stewartia, and Japanese tree lilac were up-shifted from 11.4-L classic Spinout®-treated containers (Nursery Supplies, Inc., Fairless Hills, Pennsylvania) in October 2004 and 2005. Littleleaf linden, was left in copper-treated 250XL containers until 15 March 2005 and 2006, due to their small size and then up-shifted to 11.4-L pots. In October of each year, all of the plants were placed in a peaked-RRG. The roof on the RRG was set to open at 38 °F (3 °C). Temperatures were kept above 25 °F (-4 °C) in the RRG by a forced-air propane heater. Plants were hand watered twice monthly during the winter. Settings in the RRG (flat- and peak-) were set to 55 °F (open at this temp) during the day and 45 °F at night. On 15 March 2005 and 2006, all of the plants were fertilized with 3 tablespoons 19–5–8 Osmocote® (Scott's Co., Marysville, Ohio) slow-release fertilizer. They were then moved to their respective environments: one-third of the plants were kept in the peaked-RRG, one-third was moved to the flat-RRG, and one-third was moved to a polyhouse covered with 6-mil, milky poly at OSU, Columbus, Ohio on 15 March 2005 and 2006. Settings in the peak-roof and flat-roof RRG were also changed. The sidewalls were set to open at 55 °F (13 °C) in both environments. The roofs remained closed unless temperatures exceeded 75 °F (24 °C) through the remainder of the growing season. On 1 April 2005, sidewalls were reset to open at 65 °F (18 °C), and on 15 April 2005, sidewalls were set to open at 75 °F (24 °C) and kept that way for the remainder of the season. However, if temperatures exceeded 85 °F (29 °C) during the day, then the roof was set to close for shading, and the sidewalls remained open for air circulation. The poly was left on the polyhouse until 15 May of both years (first frost-free day for Columbus, Ohio) when it was removed. Growth was evaluated in June, August, and October of both years by collecting leaf area, caliper, height, and dry weights of shoots and roots. Liners were top pruned once they reached the height that they achieved in 2005 to see if more caliper growth could be achieved via top pruning, with the exception of oak. In 2005, some oaks did not achieve 4 ft so pruning was not necessary. Irrigation was conducted with inline emitters, delivering 0.6 gal (2271 mL per hour = 1136 mL /day in three equally timed periods were employed per day, at 10 AM, 2 PM, and 4 PM. Time per interval was 10 min from 15 March to about 1 June, 12 min from 1 June to 1 Sept., and 10 min from 1 Sept. to Oct..

Comparison of Four Tree Liner Production Environments on Transplant Survival. Three-gallon containers of the five species grown in the optimum environment and species for containerized tree liner production study were out-planted into fields at OSU Waterman Farm, Columbus, Ohio, in November 2005 and Willoway Nurseries, Avon, Ohio, in November 2006. The plants at Willoway Nurseries were up-shifted to 7-gal containers in March 2007 and out-planted in PIP socket pots. Plants were also planted from 3-gal containers from Willoway Nurseries into nursery fields at Split Rail Nursery, Circleville, Ohio, in March 2007. The PIP 7-gal containers at Willoway were replicated five times and randomized using a completely randomized design with tree liners produced from the OSU peaked-RRG, flat-RRG, polyhouse, and (west coast) bareroot environments. Temperatures were recorded for daily highs and lows at OSU, Willoway Nursery, and Circleville, Ohio. Heights and calipers were recorded in September 2007.

RESULTS AND DISCUSSION

Optimum Environment and Species for Containerized Tree Liner Production. As reported in Mathers et al. (2006) #3 containerized tree liners of easy-to-grow species from RRG's planted in October 2003 had 0% mortality versus field bareroot production at 42% after out-planting into nursery fields to grow on as specimen trees. Using a linear regression ($y = 3.5752x + 10.048$, $R^2 = 0.9432$) to estimate growth, bareroot liner caliper growth will not reach 2 inches until June 2009 (Fig. 1). This represents a 40% cut in production time using RRG tree liners versus bareroot.

Environment pooled over species, date, and year for five species of difficult-to-grow species was significant for caliper ($p = 0.04$) and height ($p = 0.02$). Calipers and heights were significantly larger in either RRG flat- or peak- versus the polyhouse (data not shown). No significant differences for caliper or height were present between the two RRG environments, peak or flat. Although the height and caliper differences of 7.7 cm and 0.5 mm, respectively between RRG and poly, were significant — they were not sufficient to justify the expensive of a RRG construction over a polyhouse for containerized tree liner production. However, the RRG reduced environmental fluctuations between years, thus increasing cropping consistency by 30%. This increase in consistency was statistically and economically significant and justifies the RRG construction versus a polyhouse for tree liner production. The variability between years was highly significant in the polyhouse for height (Fig. 2), caliper, and root weight (data not shown). The root weights were 5 g lower, averaged over species, in the polyhouse in 2005 versus 2006. A more consistent crop could be grown year to year in either RRG versus the polyhouse, with variability being species-dependent (Fig. 4). Only *Syringa* showed no variability, year-to-year with environment (Fig. 4).

Percent saleable (120 cm) height was achieved earlier in the RRGs versus the polyhouse. Yellowwoods by August in the flat-RRG had 50% saleable, the peak-RRG 63%, and polyhouse only 20%. In October, only one yellowwood made it to saleable size in the polyhouse. In October, 50% the oaks in the flat- or peak-RRG peak were of saleable size, however, only 33% were saleable in the polyhouse. The *Stewartia* grew to saleable size in all environments by October, however, in August, in the flat-RRG roof 58% were saleable, 83% in the peak-RRG, and 42% in the polyhouse. The species with the largest heights and calipers in 2005 and 2006 was Japanese tree lilac followed by linden. Lilac was also the most consistent species from year to year. Yellowwood and red oak were the least consistent species and grew best in 2005. Linden and *Stewartia* grew best in 2006.

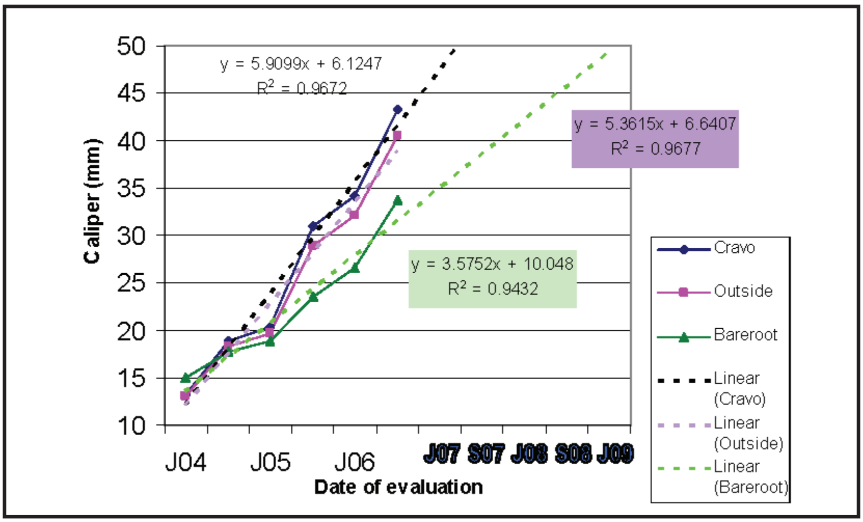

Figure 1. Out-planted (2003) field caliper measures from June 2004 to Sept. 2006 pooled over species for tree liners produced from three production environments. The abbreviations RRG, CHGO, and Bareroot signify retractable roof greenhouse, combination heated greenhouse-outdoor, and bareroot liners from the field nurseries, respectively. The interaction of environment X date was significant at ($p < 0.0001$). Linear regressions estimate time to reach 2-in. caliper for liners from bareroot production ($R^2 = 0.9432$).

This study indicates even difficult-to-grow species can be produced in Ohio with good results. The RRG provides the benefits of manipulating the growing environment and scattering light, which helps reduce heat loads and, improve growth and plant canopy development. Retractable roof greenhouses are more expensive than a polyhouse and the cost deters many growers. However, the crop consistency and crop acceleration (49% – 68%, depending on species) obtained in the RRG versus the polyhouse makes their construction advantageous.

Comparison of Four Tree Liner Production Environments on Transplant Survival. On 7 April 2007 in the early morning hours of 4 AM at Willoway Nurseries low temperatures of -10 °C were experienced following several days of record high temperatures for the area. Temperatures of -7 and -8 °C were also experienced in Columbus and Circleville, Ohio. These low temperatures caused significant damage to vascular tissue in the tree liners and killed back foliage that had flushed in the warm days proceeding 7 April.

The consistency of cropping described in the results for Experiment #2 also followed through after out-planting for caliper (Fig. 3) and height (data not shown).

Measures taken in Sept. 2007 also indicated the peak- or flat-RRG are increasing in caliper significantly faster than the bareroot produced liners or the polyhouse produced liners. Averaged over species and one growing season, caliper (18.9 mm) and height (166.43 cm) of RRG liners were significantly larger than bareroot liners (3.6 mm and 26 cm) or 82% and 84% larger (Fig. 3). Tree liners produced in peaked RRGs also had 75% and 80% larger heights and calipers, respectively, versus bareroot liners after out-planting to Split Rail Nursery and OSU nursery fields and measured in Oct. 2007. In 2006, #3 containerized tree liners from bareroot production had 87% mortality versus RRGs with 27% mortality after out-planting to #7 containers in PIP fields (Fig. 5).

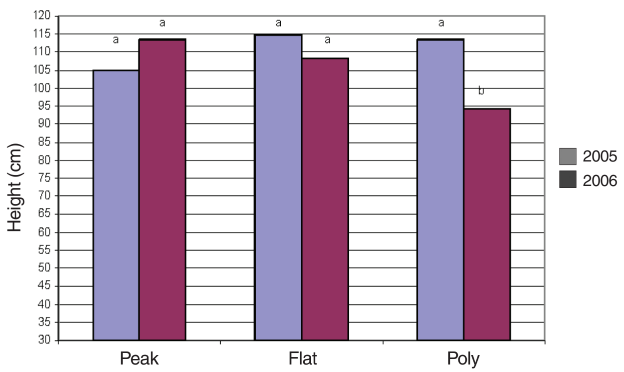

Figure 2. Height measures in centimeters pooled over five species and three evaluation dates of June, August and October per year for three production environments: peaked- and flat-retractable roof greenhouses (RRGs) (Cravo Equipment, Ltd., Brantford, Ontario, Canada) and a polyhouse at Ohio State University, Columbus, Ohio and 2 years 2005 and 2006. Different letters signify least significant difference (LSD) P = 0.05.

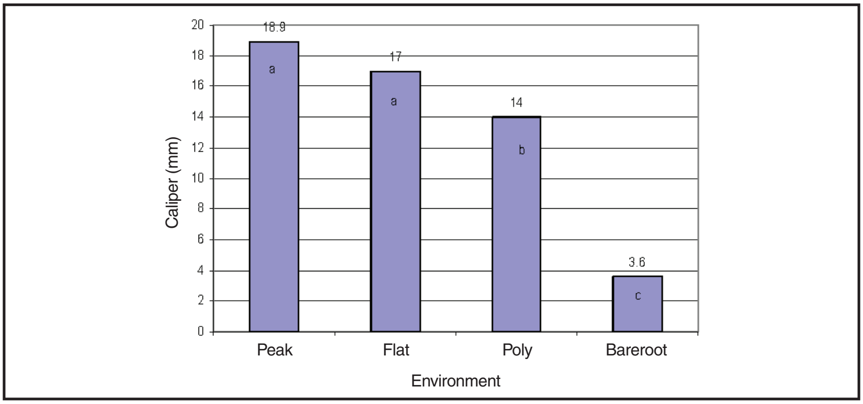

Figure 3. Caliper measures in millimeters pooled over five species from #3 (11.4 L) containers produced in four production environments peaked-and flat- retractable roof greenhouses (RRGs) (Cravo Equipment, Ltd., Brantford, Ontario, Canada), a polyhouse at Ohio State University, Columbus, Ohio or bareroot 5 months after-out planting to #7 containers and harsh March conditions at Willoway Nurseries, Inc., Avon, Ohio. Different letters signify least significant difference (LSD) P = 0.05.

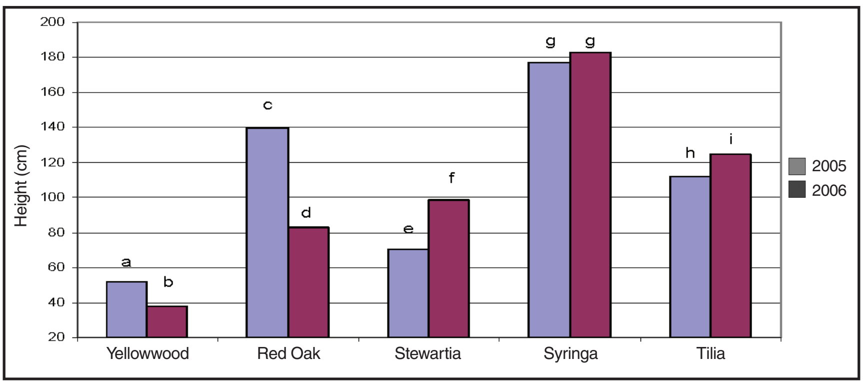

Figure 4. Height measures in centimeters for tree liners pooled over three environments (peaked- and flat-retractable roof greenhouses (RRGs) (Cravo Equipment, Ltd., Brantford, Ontario, Canada) and a polyhouse) at Ohio State University, Columbus, Ohio and three evaluation dates June, August and October per year for five species yellowwood, (*Cladrastis kentukea*), red oak (*Quercus rubra*), stewartia (*Stewartia pseudocamellia*), Japanese tree lilac (*Syringa reticulata* 'Ivory Silk'), and littleleaf linden (*Tilia cordata* 'Greenspire'). The interaction of year and species was significant P = 0.0001. Different letters signify least significant difference (LSD) P = 0.05.

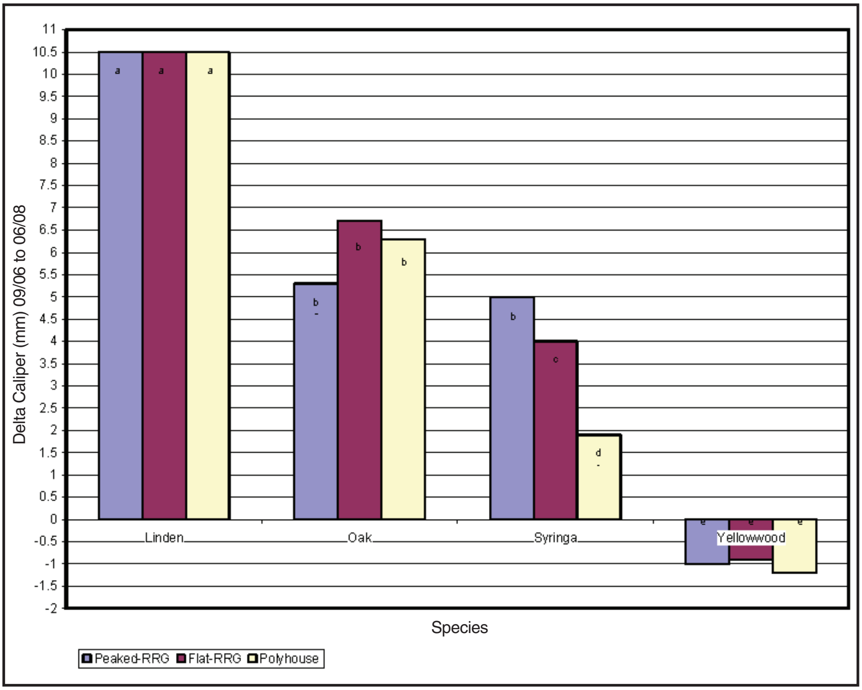

Figure 5. September 2006 (out-planted) to June 2008 field caliper Δ, environment X species interaction of tree liners (P = 0.0040). Different letters signify least significant difference (LSD) P = 0.05. Environment effects were greater with time in out planting. Yellowwood had 33% mortality in the peaked RRG, 55% in the flat roof RRG, and 55% in the polyhouse. *Syringa* had 0% mortality in the peaked RRG, 8% in the flat roof RRG, and 25% in the polyhouse.

CONCLUSIONS

The modified environment of the RRG provides advantages in the production of difficult-to-grow tree liner species and increased out-plant survival in severe spring-frost conditions versus traditional bareroot produced liners. Liners produced in RRGs have also been found to surpass bareroot produced liners in quality, growth, mortality rates and time to marketable size after transplanting into Ohio nursery fields and PIP under normal spring conditions. The less expensive structure of a polyhouse was not found to produce liners with the same cropping consistency or increased survival under severe spring-frost conditions as afforded with the RRG structure.

Midwest U.S.A., Eastern seaboard, and Southern U.S.A. nursery growers import conservatively $200 million worth of tree liners annually from traditional liner production regions such as the West Coast. Growers in these nontraditional liner production regions have been reluctant to enter into tree liner production mainly due to shortened growing seasons. Retractable-roof greenhouses make tree liner production viable in these locations via extending the growing season, temperature modification, accelerating caliper tree production, increase cropping consistency and expand existing markets. Gasoline prices are currently soaring and other transportation issues continuing to add challenges to transporting plant material long distances. It makes sense to consider production methods that are more sustainable and increase the local economy.

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