Accelerated Tree Liner Production in Retractable Roof Greenhouses©

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Since 2002 trials on containerized tree liner production under retractable-roof greenhouses (RRGs) have indicated that it is possible to achieve faster production times in pot-in-pot (PiP) and field tree systems; increased crop consistency because of an improved environment and fewer losses; and new or expanded markets for higher priced, difficult-to-grow species.

In 2004, 11.4-L (3-gal) containerised tree liners grown under RRGs had 0% mortality after planting-out into nursery fields to grow on, while mortality of field bare root production *Quercus rubra* was 42%. Averaged over all species in the trials, RRG liners reached saleable size (50-mm caliper) 2 years sooner than bareroot liners, representing a 40% reduction in production time.

In 2006, 11.4-L containerized tree liners from RRGs had 27% mortality, while mortality from field bareroot production was 87% after potting on into 26.5-L (7-gal) containers and stood in harsh conditions in PiP fields. Averaged over all species in the trials, and from 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).

In only 4 months, between 1 May and 30 Aug. 2007, heights and calipers of 178 cm and 9.9 mm *Cercis canadensis*; 146 cm and 9.7 mm *Tilia cordata* 'Green Spire'; and 118.4 cm and 7.4 mm *Acer* × *freemanii* 'Jeffersred', Autumn Blaze™ Freeman maple liners were produced at Ohio State University, Columbus, Ohio.

This study supported our hypothesis that RRG liners can be double-cropped, accelerating production further. We are currently working with 10-mm caliper liners that are double-cropped out of RRGs to produce 50-mm-caliper PiP container trees in 2 years, representing a 67% reduction in production time compared with conventional nursery practices.

INTRODUCTION

Pot-in-pot (PiP) consists of a planted container, placed in a holder pot that has been permanently placed in the ground. Pot-in-pot enables three times more plants to be produced per unit of land area than conventional field production; plants are harvested in a shorter period of time; there is greater potential for mechanization; labor and equipment needs for 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 are approximately one-third of the cost of peak-roof houses to construct (Mathers, 2001). The retractable roof design allows 90% roof retraction, and has roll-up end walls and side walls.

Research at Ohio State University (OSU) has found that RRGs (Cravo Equipment, Ltd., Brantford, ON, Canada) 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 by 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. Our studies are aiming to help growers accelerate cropping and increase productivity of PiP and RRG installations to make them more cost-competitive.

MATERIALS AND METHODS

Out-Planted Field Evaluation of Retractable-Roof Greenhouse Versus Bareroot-Grown Tree Liners. At OSU Waterman Farm, Columbus, Ohio, in heavy clay soils, four species of tree liners were transplanted from three growing environments. Trees were irrigated and fertilised as per Mathers et al. (2005).

The three environments where liners had been grown were a peaked-RRG (in 11.4-L Spinout®-treated containers); a combination of heated greenhouse followed by outdoor production (CHGO) (also in 11.4-L containers), both at OSU, Columbus, Ohio, and bareroot liners from Pacific Northwest Nursery fields, Canby, Oregon (PNW). The OSU liners had been produced according to the methods described by Stoven et al. (2005).

The OSU liners were planted in the field on 5 Oct. 2003, and bareroot liners were planted (when traditionally available for planting in Ohio) on 26 April 2004 after hydrating the roots in a 5 °C cooler for 2 days. All plants were trained to 2-m-tall bamboo stakes at planting. In Aug. 2005, the bamboo stakes were replaced with TMO-PRO stakes (T-MATE-O, Charlestown, Indiana).

The four species evaluated were, *Acer* ×*freemanii* 'Jeffersred', Autumn Blaze™ Freeman maple (maple), *Malus* 'Prairie Fire' (crabapple), *Cercis canadensis* (redbud), and *Quercus rubra* (red oak). Growth measures of height and caliper (taken at 15 cm) were recorded at planting and June and Sept. 2004, 2005, and 2006, for a total of six measures. Average initial heights and calipers for redbud, maple, crabapples, and oaks out-planted from the RRG were as cited in Mathers et al., 2005.

At planting, compared with the RRG or CHGO production environments, the PNW liners had:

- redbud: less height, greater caliper;
- maple: greater height, greater caliper;
- crabapple: less height, less caliper;
- oak: greater height, greater caliper.

In early Nov. 2003, all the RRG and CHGO trees were pruned according to normal nursery practices. No pruning was done to bareroot liners at time of planting. Perennial ryegrass was seeded in Fall 2003 between the rows and mowed as required. Between row spacing is 12 ft (4 m) and in-row 6 ft (2 m). Height and caliper from the six dates of evaluation were statistically analyzed.

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 growing environments were tested: peaked-roofed and flat-roofed RRG and a Rutgers'-style polytunnel at OSU, Columbus, Ohio. If the polytunnel or flat RRG produced liners with similar growth and quality to those from the peaked RRG, then Midwest liner production could be more attractive to a larger number of nursery producers because of their lower start-up and construction costs.

The five species selected for the study were: *Cladrastis kentukea* (yellow-wood), a difficult-to-acclimate species; *Q. rubra* (red oak), coarse rooted and in previous studies requiring at least 2 years to reach marketable size; *Stewartia pseudocamellia*, a species prone to root rot diseases; *Syringa reticulata* 'Ivory Silk' (a lilac) and *Tilia cordata* 'Greenspire' (a lime/linden), two species in short supply as bareroot liners.

The trial was repeated over 2 years, 2005 and 2006, so that environments could be replicated. Seedlings of yellow-wood, red oak, stewartia, and lilac were potted on from 11.4-L classic Spinout®-treated containers in Oct. 2004 and 2005. The limes were left in copper-treated 250-XL containers until 15 March 2005 and 2006 due to their small size, then potted on into 11.4-L pots.

In October of each year, all of the plants were placed in a peaked RRG. The roof was set to open at 3 °C. Temperatures were kept above -4 °C by a forced air propane heater. Plants were hand watered twice monthly during the winter.

On 15 March 2005 and 2006, all of the plants were fertilised with 3 tablespoons 19N-5P-8K Osmocote® controlled-release fertilizer. They were then moved to one of three environments: one-third of the plants were kept in the peaked-roof RRG, one-third was moved to a flat-roof RRG, and one-third was moved to a polyhouse covered with milky polythene, at OSU, Columbus, Ohio.

On 15 March 2005 and 2006, settings in the peak-roof and flat-roof RRG were changed. The sidewalls were set to open at 13 °C in both environments. The roofs remained closed unless temperatures exceeded 24 °C through the remainder of the growing season. On 1 April 2005, sidewalls were reset to open 18 °C, and on 15 April 2005, sidewalls were re-set to open at 24 °C for the remainder of the season. However, if temperatures exceeded 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 polytunnel until May 15 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 (not oak) 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. In 2005, some oaks did not achieve 1.2 m, so pruning was not necessary.

Irrigation was via in-line emitters, delivering 2.27 $L \cdot h^{-1}$ in three equally timed periods per day (10 am, 2 pm, and 4 pm). Time per interval was 10 min from 15 March to 1 June, 12 min from 1 June to 1 Sept., and 10 min. from 1 Sept. to Oct.

Double Cropping Tree Liner Production in Retractable-Roof Greenhouses. Seedlings *of T. cordata* 'Greenspire', *C. canadensis, A.* ×*freemanii* 'Jeffersred', and Autumn Blaze™ Freeman maple were potted-on from copper-treated 250-XL to 11.4-L classic Spinout treated containers on 1 May and placed in the peak-roof RRG, OSU, Columbus, Ohio. Plants were divided into three irrigation regimes of three, two, or one watering interval that all delivered 2.27 $L \cdot h^{-1}$ of water daily. Plants were also divided into three fertilizer regimes: 3 tablespoons per pot 19-5-8 Osmocote controlled-release fertiliser; a 20N-20P-20K liquid feed; or both.

Sidewalls and roof of RRG were set to open at 24 °C. If temperatures exceeded 29 °C during the day, then the roof was set to close for shading, and the sidewalls remained open for air circulation.

RESULTS AND DISCUSSION

Out-Planted Field Evaluation of Retractable-Roof Greenhouse versus Bareroot-Grown Tree Liners. As reported in Mathers et al. (2006), containerised tree liners from RRGs planted in October 2003 had 0% mortality (compared with field bareroot production at 42% mortality) after planting out. The greatest tree mortality occurred in red oak, with five of 12 bareroot liners having died by Sept. 2004 (42% mortality). Averaged over species, RRG liners reached saleable size (50-mm caliper) 2 years sooner than the bareroot liners. Using a statistical analysis we estimate bareroot liner caliper growth will not reach 50 mm until June 2009 (Fig. 1). This represents a 40% cut in production time using RRG tree liners compared with bareroot.

The RRG-grown liners produced significantly greater caliper increases in the field compared with bareroot liners (data not shown). The effects of the original growing environment on caliper were not significant for the first year after planting out; however, the production environment effects became more significant in the second and third year after planting (Fig. 1). On average, heights were increasing at 15.8 cm per season.

Optimum Environment and Species for Containerized Tree Liner Production. The effect of production environment was significant for caliper and height when pooled over species, date, and year. Calipers and heights were significantly larger in crops from either flat- or peak-RRG than in those from the polytunnel (data not shown). The type of RRG made no significant difference to caliper or height. Although the height and caliper differences of 7.7 cm and 0.5 mm, respectively, between RRG and polytunnel treatments were significant, they were not sufficient to justify the greater expense of RRG construction.

However, the RRG reduced environmental fluctuations between years, thus increasing cropping consistency by 30%. This increase in consistency was statistically and economically significant and does justify the RRG construction instead of a polytunnel for tree liner production.

The variability for height, caliper, and root weight between years was highly significant in the polytunnel (Fig. 2). The root weights were 5 g lower, averaged over species, in the polytunnel in 2005 compared with 2006.

A more consistent crop could be grown year to year in either type of RRG than in the polytunnel. Saleable height (120 cm) was achieved earlier in the RRGs than in the polytunnel. By August, 50% of the yellow-woods in the flat RRG were saleable, 63% in the peak RRG, and 20% in the polytunnel. In October, only one yellow-wood made it to saleable size in the polytunnel. In October, 50% of the oaks in the flat or peak RRG peak were of saleable size; 33% in the polytunnel. 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 polytunnel. The species with the largest heights and calipers in 2005 and 2006 was the lilac, followed by the lime. The lilac was also the most consistent species from year to year. Yellow-wood and red oak were the least consistent species and grew best in 2005. Lime and stewartia grew best in 2006.

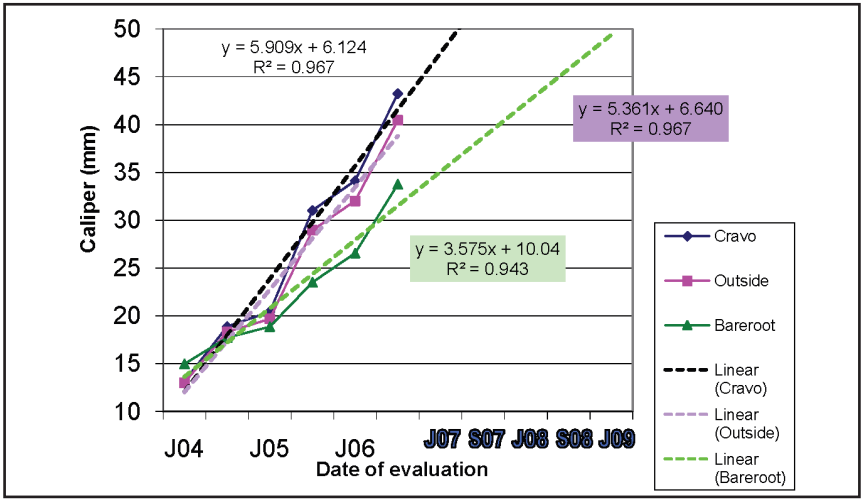

Figure 1. Out-planted (2003) field caliper measures from June 2004 to Sept. 2006 pooled over species for tree liners produced from three production environments. The abbreviations RRG, CHGO, and Bareroot signify retractable roof greenhouse, combination heated greenhouse-outdoor, and bareroot liners from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

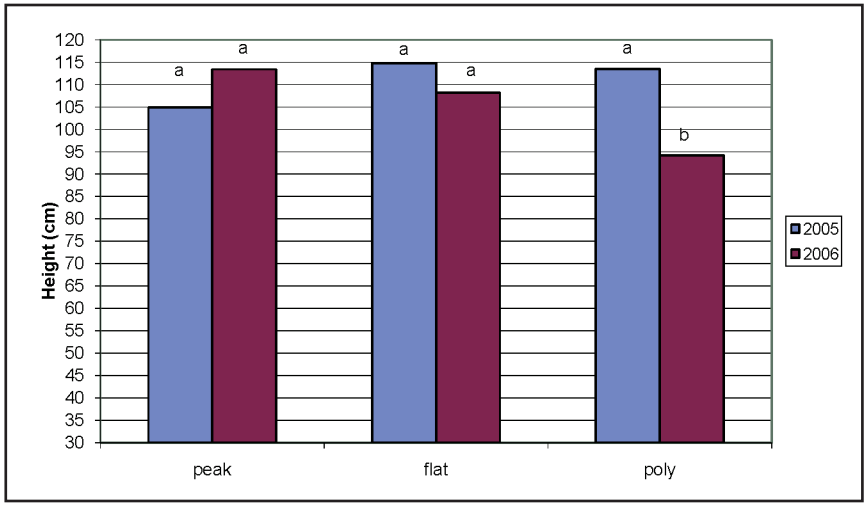

Figure 2. Height measures in centimeters pooled over five species and three evaluation dates of June, Aug. and Oct./year for three production environments: peaked and flat retractable roof greenhouses (RRGs) (Cravo Equipment, Ltd., Brantford, Ontario, Canada) and a polyhouse at Ohio State University,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

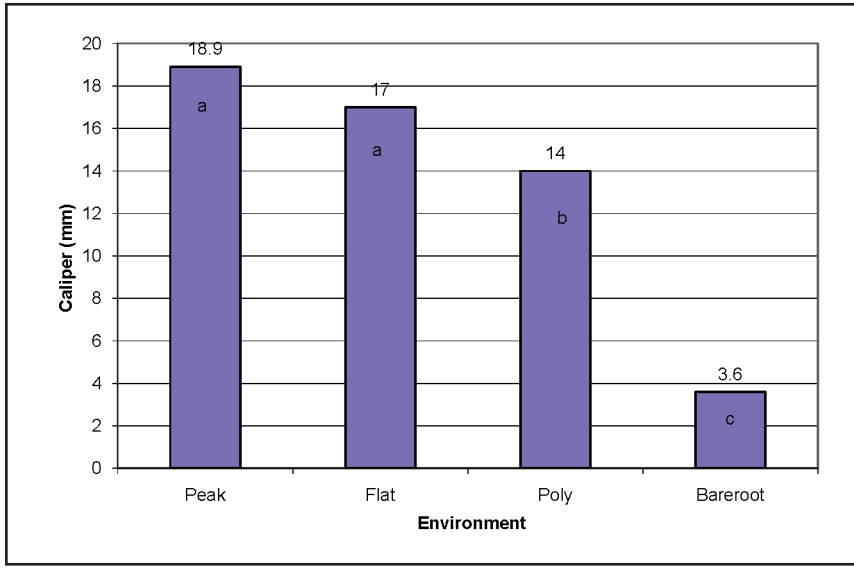

Figure 3. Caliper measures in millimeters pooled over five species from #3 (11.4-L) containers produced in four production environments: peaked and flat retractable roof greenhouses (RRGs) (Cravo Equipment, Ltd., Brantford, Ontario, Canada), a polyhouse at Ohio State University, Columbus, Ohio, or bareroot 5 months after-out planting to #7 (26.5-L) containers and harsh March conditions at Willoway Nurseries, Inc., Avon, Ohio. Different letters signify least significant difference (LSD) P = 0.05.

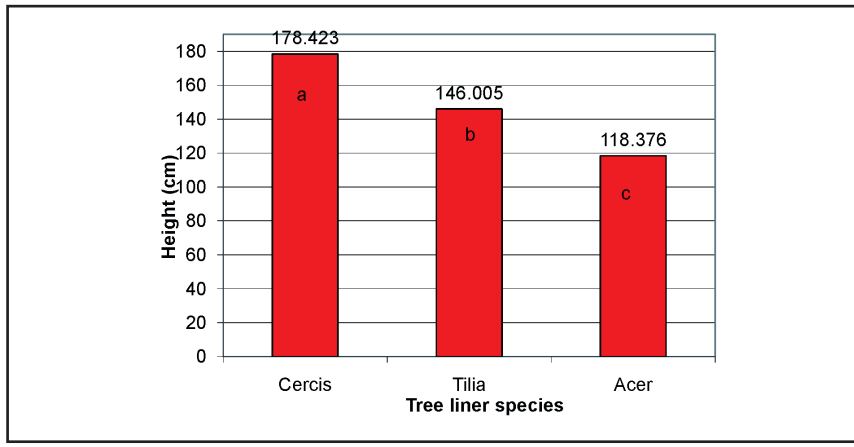

Figure 4. September 2007 height measures pooled over fertilizer and irrigation treatments for liners of *Tilia cordata* 'Greenspire' (green spire linden), *Cercis canadensis* (eastern redbud), and *Acer* ×*freemanii* 'Jeffersred', Autumn Blaze™ freeman maple produced in a peak retractable roof greenhouse between 1 May and 30 Aug. 2007 ($p \leq 0.0001$) at Ohio State University, Columbus, Ohio. Different letters signify least significant difference (LSD) P = 0.05.

This study indicates that even difficult-to-grow species can be produced in Ohio with good results. Growers can use a RRG to manipulate the growing environment, including choice of cladding material to scatter incoming light, which helps reduce heat loads and improves growth and plant canopy development.

Retractable roof greenhouses are more expensive than polytunnels, and the cost deters many growers. However, the crop consistency and crop acceleration (49% to 68% depending on species) obtained in the RRG compared with the polytunnel make their construction advantageous. The consistency of cropping also follows through after planting out for caliper (Fig. 3) and height. In 2006, 87% of containerised (11.4-L) tree liners from bareroot production died after planting out, compared with 27% mortality in the trees that had been grown in RRGs then outplanting to 26.5-L containers in harsh spring conditions in PiP fields at Willoway Nurseries, Avon, Ohio. Measurements taken in September 2007 indicate that trees sourced from either the peak-roof or flat-roof RRG increased caliper significantly faster than those from bareroot-produced liners or the polytunnel-produced liners.

Double Cropping Tree Liner Production in Retractable Roof Greenhouses. In only four months, between 1 May and 30 Aug. 2007, heights (Fig. 4) and calipers of 178 cm and 9.9 mm *C. canadensis*; 146 cm and 9.7 mm *T. cordata* 'Greenspire'; and 118.4 cm and 7.4 mm *A. rubrum* 'Jeffersred', Autumn Blaze™ Freeman maple liners were produced in a peak RRG at OSU, Columbus, Ohio. This study supported our hypothesis that, in a RRG, liners can be double-cropped to accelerate production further.

We are currently working with 10-mm-caliper liners that are double-cropped out of RRGs to produce 50-mm-caliper PiP container trees in 2 years — representing a 67% reduction in production time compared with conventional nursery practices.

The crop we considered easiest to grow, the maple, made the least height and caliper after 4 months compared with the more difficult-to-grow redbud or lime. This observation supported other OSU studies where the RRG liner system simplified the production of difficult-to-grow species.

LITERATURE CITED

Mathers, H.M. 2001. The future is in retractables: Nursery stock production in retractable roof greenhouses. The Buckeye. August. pp. 16–17, 19, and 31. Mathers, H.M., L.T. Case, A. Acuna, M. Bigger, and D. Struve 2006. Sense and sensibility: Container grown tree liners. Amer. Nurseryman. 204(11):26–28, 30–31.

Mathers, H.M., L.T. Case, E. Grosskurth, and **M. Bigger.** 2005. Field caliper tree production using retractable roof greenhouse grown liners. Southern Nurserymen Assoc. Res. Conf. 50:164–167.

Mathers, H.M., S.B. Lowe, C. Scagel, and **L.T. Case.** 2006. Abiotic factors influencing root growth of woody nursery plants in containers. HortTechnology. 17:151–162.

Mathers, H., D. Struve, and **A. Stoven.** 2002. Tree liner production in Ohio. The Buckeye. November. pp. 14-17.

Stoven, A.A., H.M. Mathers, and **D.K. Struve.** 2006. Fertilizer application method affects growth, nutrient and water use efficiency of container-grown shade tree whips. HortScience 41:1-7.