PRODUCTION METHOD AFFECTS GROWTH AND ROOT REGENERATION OF LEYLAND CYPRESS, LAUREL OAK AND SLASH PINE[1]

by J. Roger Harris and Edward F. Gilman

Abstract. Leyland cypress, laurel oak and slash pine were grown for 18 months in plastic containers, in fabric containers or directly in the field and then transplanted into field soil. There was no difference in growth between field-grown and fabric container-grown trees for laurel oak or slash pine, but field-grown leyland cypress were taller than fabric container-grown trees. Container-grown trees were smallest for all three species. Shoot : root dry weight ratio was smallest on container-grown trees because little of the root system is lost during transplanting compared to fabric and field-grown trees. Ten weeks after transplanting, weight of regenerated roots on fabric container-grown leyland cypress and slash pine was greater than on field-grown trees. Field-grown slash pine regenerated less root weight than trees produced by other production methods. Production method did not affect root regeneration of laurel oak.

Résumé. Le cyprès de Leyland, le chêne à feuilles de laurier et le pin d'Elliot étaient mis en croissance pour 18 mois dans des conteneurs en plastique, des conteneurs de tissu ou directement dans le champ et transplantés par la suite in pleine terre dans le champ. Il n'y avait aucune différence de croissance entre la croissance en plein champ et celle en conteneurs de tissu pour le chêne à feuilles de laurier ou le pin d'Elliot, mais le cyprès de Leyland était plus grand en plein champ que les arbres en coteneurs de tissu. Les arbres en conteneurs de plastique étaient plus petits pour les trois espèces. Le ratio en poids pousses:racines sèches était plus faible pour les arbres en conteneurs de plastique parce qu'une plus faible part du système racinaire est perdue lors de la transplantation comparé au conteneur de tissu et au plein champ. Dix semaines après la transplantation, le poids en racines regénérées pour le cyprès de Leyland et le pin d'Elliot en conteneurs de tissu était plus grand que pour les arbres en plein champ. Le pin d'Elliot en plein champ regénérait moins de racines en terme de poids que les arbres produits par d'autres méthodes de production. La méthode de production n'affectait pas la regéneration des racines chez le chêne à feuilles de laurier.

Landscape-sized trees are produced in field nurseries and harvested bare-root or balled and burlapped (B&B), or are produced in containers. Recently, nursery operators have begun to grow trees in fabric containers in the ground. Reported advantages of growing trees in fabric containers vs. in-ground field production include 1) less effort in digging, 2) much higher portion of the root system retained within the root ball, 3) reduced root ball weight, and 4) usefulness in sandy soils unsuitable for normal B & B production. Reported disadvantages include increased initial costs, slower planting and the need for drip irrigation in the nursery (16). Post-transplant establishment may be enhanced for trees produced in fabric containers because of a potential increase in the percentage of roots harvested (24).

Root dry weight within the root ball of live oak *(Quercus virginiana)* and sweet gum *(Liquidambar styraciflua)* was greater in fabric containers than in those grown directly in the field or in plastic containers, but there were no differences among production methods for 5 other species (12). Fuller and Meadows (6) report that for 4 of 5 species tested, root weight within the root ball was greater in fabric containers than in the traditional field-grown root ball.

The capacity for rapid regeneration of roots may be the most crucial physiological factor for survival of transplanted trees (5, 18, 23). New root growth results from elongation of intact and initiated lateral and adventitious roots (17, 19, 21). The ability of planted trees to regenerate new roots quickly depends upon environmental factors at the site and morphological and physiological characteristics of the tree at the time of planting (3). The degree of alteration of shoot : root ratio by transplanting may be a primary factor in the severity of transplant shock (22). Trees with higher shoot : root ratios reportedly transplant poorly (14) and grow more slowly (10) after transplanting.

Most transplant research has compared field-grown trees harvested bare-root to field-grown trees harvested with root balls intact, either by machine or balled and burlapped. Growth of dor-

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mant green ash *(Fraxinus pennsylvanica)* 'Platmore', black ash *(Fraxinus nigra)* 'Fallgold', hackberry, *(Celtis occidentalis)*, and amur cherry *(Prunus maackii)* transplanted with a tree spade was 4 to 10 times greater than comparable-sized trees moved bare-root (21). 'Grey Rock' juniper *(Juniperus virginiana* 'Grey Rock') and 'Keteleeri' juniper *(Juniperus chinensis* 'Keteleeri' transplanted bare-root grew as well as those transplanted B&B, but Norway spruce *(Picea abies)* and pyramidal white cedar *(Thuja occidentalis* 'Pyramidalis') transplanted less successfully bare-root than B&B (15).

There is little research comparing transplanted container-grown plants with B&B plants. Blessing and Dana (2) found that 16 weeks after transplanting, field-grown 'Sea Green' juniper *(Juniperus chinensis* 'Sea Green') had a greater root spread and more regenerated root dry weight than container-grown plants. Few post-transplant comparisons have been made among field-grown, container-grown, and fabric container-grown trees. This study was designed to compare growth in the nursery, shoot : root ratio at the time of transplanting and root regeneration after transplanting of nursery stock produced by these three methods.

Materials and Methods

Fifty-four each of laurel oak *(Quercus hemisphaerica)*, slash pine *(Pinus elliottii)*, and leyland cypress (x*Cupressocyparis leylandii)* in 15 cm (6 in) wide X 15 cm (6 in) deep (3-liter, 1 gallon) black plastic containers were selected for uniformity and planted in a randomized complete block design on 28 July and 10 and 11 Aug. 1988. Eighteen trees of each species were planted in 25 cm (10 in) wide X 25 cm (10 in) deep (10-liter, 3 gallon) black plastic containers (Model 030, Lerio, Inc., Mobile, Ala.) in 3 pine bark : 2 native peat : 1 sand media (v:v:v) supplemented with 0.90 kg (2 lb) Perk (Vigoro Industries, Fairview Heights, Ill.), 3.5 kg (8 lb) dolomitic limestone, and 0.60 kg (1.3 lb) superphosphate (20% P_2O_5) per m^3 (1.3 yd^3). They were replanted into 34 cm (13.5 in) wide by 30 cm (12 in) deep (25-liter, 7 gallon) black plastic containers (Model 7g Lindco Industries, Ft. Lauderdale, Fla.) on 5 April, 1989. The plastic containers were placed inside slightly larger empty containers to buffer media temperature (13). Thirty-six of each species were planted in an Arrendondo fine sand amended to a pH of 6.4 with granular sulfur. Eighteen of these were in 25 cm (10 in) wide by 25 cm (10 in) deep fabric containers (Root Control, Inc., Oklahoma City, Okl.), and 18 were planted directly in the field.

Trees in plastic containers were irrigated daily with 3 cm (1.2 in) of water by individual microemitters except for 15 Dec. - 1 Feb. when irrigation was supplied on alternating days. Trees in fabric containers and in the field were supplied with overhead irrigation to insure a minimum of 3.5 cm (1.4 in) of water per week. All trees received Osmocote 18-6-12 (Sierra Chemical Co., Milpitas, Calif.) immediately after planting at 50 g (1.8 oz) per tree evenly distributed over a 12.5 cm (5 in) radius from the trunk. Trees were refertilized 5 April, 1989 at 110 g (4 oz) per tree evenly distributed over a 17 cm (6.7 in) radius. Weeds were controlled with oxyfluorfen + oryzalin applied every 6 months at 1 kg/100 m^2 (0.2 lb/100 ft^2).

Trunk diameter 2.5 cm (1 in) above the soil line and height were measured at planting. Final height, trunk diameter, and crown width were measured on 8 Jan. 1990. The largest and smallest tree in each production method was discarded for each species. Four trees from each production method and species (36 trees) were selected at random, harvested on 15 Jan. and dried to a constant weight. Harvested root balls were the confines of the containers for container-grown and fabric container-grown trees. Root ball size for trees produced in the field was 46 cm (18 in) wide x 30 cm (12 in) deep for laurel oak, 51 cm (20 in) wide x 34 cm (13.5 in) deep for slash pine, and 41 cm (16 in) wide x 27 cm (11 in) deep for leyland cypress. Root balls were sized according to industry standards (1).

In late January 1990, 6 trees from each production method and species (54 trees) were selected at random and transplanted to an adjacent field and arranged in a randomized complete block design. Plastic containers were removed at planting, and fabric containers were cut vertically, and gently removed from the root balls. Trees grown directly in the ground were dug by hand,

and the root balls were tightly covered with burlap. Trees were irrigated with 3 cm (1.2 in) of water daily supplied by 2 microemitters per tree. On 2-4 April 1990, root systems were hand excavated and the maximum lateral extension of roots from the root ball was measured on four sides (N, E, S, W) of each tree. The mean was recorded as the average maximum root extension. All roots growing outside of the original root ball were dried to a constant weight. Data were analysed with analysis of variance.

Results and Discussion

Method of tree production affected growth of all three species in the nursery. Trees in plastic containers grew the least in height (Table 1). Field-grown leyland cypress trees were taller than those produced in fabric containers, but there was no difference between the two production methods on laurel oak or slash pine. Height of trees in fabric containers was similar to that of field-grown trees on most species tested in Louisiana (5) and on 2 of 4 species tested in Tennessee (20).

Leyland cypress and slash pine grown in the nursery in plastic containers had a smaller trunk diameter increase and crown spread than trees grown in the field or in fabric containers. There were no differences among production methods in trunk diameter increase on laurel oak. However, those in fabric containers had a larger crown spread than those in plastic containers. Despite these differences there was no effect of production method on shoot dry weight of leyland cypress and laurel oak (Table 2). Fabric container-grown slash pine trees had more shoot dry weight than those in plastic containers.

Volume of the root ball on fabric container-grown trees was less than half of that on field-grown trees. However, there was no difference in root dry weight. This shows that root density (root dry weight per unit soil volume) was increased within the fabric container for all species. Fuller and Meadows (6) also showed that root density increased on all 5 species tested. Ingram et al. (12) reported a similar redistribution of roots on live oak, sweet gum and 'East Palatka' holly, but not on 4 other species. Root density increased within the fabric container root ball for all sized roots on laurel oak and East Palatka holly (Gilman and Beeson, unpublished).

Shoot : root dry weight ratios at transplanting were lowest on trees in plastic containers (mean = 2.7 : 1) because few roots were lost during

Table 1. Height, trunk and crown growth of leyland cypress, laurel oak and slash pine during 17 months of production in plastic containers (PC), directly in field soil (FG) and in fabric containers (FC).

Tree	Production method	Height increase^z (m)	Trunk diameter increase^z (cm)	Final crown width^z (m)
Leyland cypress	PC	0.56c^y	2.1b	0.85b
	FG	0.94a	2.9a	0.97a
	FC	0.81b	2.9a	0.94a
Laurel oak	PC	0.79b	2.2a	1.00b
	FG	1.22a	2.4a	1.11ab
	FC	1.13a	2.3a	1.19a
Slash pine	PC	1.05b	3.8b	0.91b
	FG	1.60a	4.9a	1.18a
	FC	1.41a	4.7a	1.14a

^zMean of 16 trees. Height and trunk diameter (2.5 cm, 1 in from soil) at the beginning of the 17 month production cycle were 0.75 m and 1.0 cm, 1.1 m and 1.1 cm, 0.61 m and 1.5 cm for leyland cypress, laurel oak and slash pine, respectively.
^yMeans for each species followed by different letters are significantly different from each other by Duncan's MRT, $P < 0.05$.

Table 2. Shoot and root growth of leyland cypress, laurel oak and slash pine during 17 months of production in plastic containers (PC), directly in field soil (FG) and in fabric containers (FC).

Tree	Production method	Shoot dry weight^zy (g)	Root dry weight^zx (g)	Shoot: root ratio^zx
Leyland cypress	PC	1113.7a^w	292.2a	3.95b
	FG	1557.9a	215.8a	7.15a
	FC	1497.5a	230.7a	6.57a
Laurel oak	PC	875.8a	561.3a	1.57c
	FG	1184.3a	383.7b	3.01a
	FC	893.5a	385.5b	231.b
Slash pine	PC	990.2b	413.2b	2.45b
	FG	1537.6ab	470.5ab	3.26a
	FC	2026.6a	594.2a	3.30a

^zMean of 4 trees.
^yTotal of trunk, twigs, leaves and berries.
^xWithin the root ball.
^wMeans for each species followed by different letters are significantly different from each other by Duncan's MRT, $P < 0.05$.

transplanting. Only a small portion of the root system was harvested at transplanting with the other two methods, resulting in a higher shoot : root ratio for trees grown in the field (mean = 4.5 : 1) and in fabric containers (mean = 4.1 : 1). Root balls of established field-grown trees contain only about 10% of the root system at transplanting (8). However, root balls on recently planted trees—such as the ones in this study—contain a larger portion of the root system (11).

The smaller shoot : root dry weight ratios on plastic container-grown trees did not correspond to greater dry weights of regenerated roots (Table 3). However, few roots were lost on these plants so they should not need to regenerate a large amount of roots in the first several months after transplanting. In addition, post-transplant conditions were optimal. The smaller shoot : root ratios may offer an advantage under less favorable soil moisture (11) or more exposed conditions.

Shoot : root ratios at transplanting were similar for fabric container and field-grown leyland cypress and slash pine. However, dry weight of regenerated roots was greater on trees transplanted from fabric containers (Table 3). On the other hand, fabric container-grown laurel oak had a lower shoot : root ratio than field-grown trees. Yet, regenerated root weight was similar for both tree production methods.

Slash pine transplanted from the field had less regenerated root dry weight than those from the other production methods. In contrast, Fuller and Meadows (7) found that root regeneration was similar on fabric-grown and field grown slash pine. Most of the root weight in the root balls of field-grown slash pine appeared to be in large-diameter roots which were severed at harvesting. Few roots regeneated from these large-diameter roots. Watson and Himelick (23) made a similar observation in severed, large-diameter roots on green ash. Bald cypress transplanted from fabric containers was the only tree of 5 tested which regenerated more root weight than field-grown trees (7). There appears to be no consistent relationship between tree production method or shoot : root ratio and root regeneration following transplanting.

Trees produced in fabric containers had greater root density within a smaller root ball than field-grown trees. The ultimate effects on tree growth of having initially a much branched root system exploring a smaller volume of soil still needs to be determined. But fabric container-grown trees (which were not irrigated daily after transplanting) were more water stressed and required more frequent irrigation after transplanting (11). The potential advantage of a denser root system on trees grown in fabric containers was probably negated by a loosening of the root ball when the fabric was removed at transplanting. This probably damaged fine roots and contributed to water stress. Even with careful handling, it is difficult to remove the fabric without loosening the root ball. A fabric that is easier to remove may help keep the root ball intact. Increased water stress also could have resulted from the smaller reservoir of water available to the root system due to the smaller size of the root ball (compared to container and field-grown trees). This would lead to rapid drying of soil within the root ball.

All trees survived transplanting. Roots on trees transplanted from the field grew further from the root ball than those planted from plastic containers (Table 2). *Juniperus chinensis* responded similarly (2). During the 10 weeks following transplanting, root extension on field-grown trees (mean = 33 cm, 13 in.) was similar to that on fabric container-grown trees (mean = 30.1 cm, 12 in.). This

Table 3. Average maximum extension and dry weight of regenerated roots 10 weeks after transplanting leyland cypress, laurel oak and slash pine produced in plastic containers (PC), directly in field soil (FG) and in fabric containers (FC).[z]

Tree species	*Production method*	*Average maximum extension[y] (cm)*	*Dry weight (g)*
Leyland cypress	PC	27.0b[x]	8.8b
	FG	32.0a	15.5b
	FC	29.7ab	33.9a
Laurel oak	PC	25.3b	2.3a
	FG	31.7a	3.2a
	FC	26.0ab	6.6a
Slash pine	PC	29.2b	58.0a
	FG	34.8a	11.2b
	FC	34.7a	77.9a

[z]Mean of 6 trees.
[y]Mean of 4 distances (N, E, S, W) measured from edge of root ball to farthest root tip.
[x]Mean separation within columns by species by Duncan's MRT $P < 0.05$.

growth rate was twice that on container-grown *Juniperus chinensis* transplanted in Florida (9) and 4 times that for those in Indiana (2). Rapid root extension would provide for water absorption from a greater volume of soil, and may be of greater benefit to the tree than more roots in a more limited space.

Watson (22) developed a root growth model and assumed a root spread radius increase of 45 cm (1.5 ft)/year for trees in the northern United States. Coutts (4) found that root spread radius of forest-grown 8-year-old Sitka spruce increased at a rate of 60 cm (2 ft)/year. Root spread radius was 2.7 m (9 ft), 2 years after transplanting 13 cm (5 in)-caliper live oak amounting to a 1.3 m (4.5 ft)/year increase (Gilman, unpublished). On a transplanted field-grown tree, it will take about one year per 2.5 cm (1 in) of trunk-caliper to regenerate the root system to the original pre-transplant size assuming a 1.3 m (4.5 ft)/year increase in root spread radius. It may take longer in northern climates where roots appear to grow at a slower rate (22).

Conclusions

The fabric container has given nursery operators an additional tool to produce high quality trees. As with any new product, producers and tree planters are learning together how to use it. Recent research found that trees produced in fabric containers regenerate roots after planting in the landscape at about the same rate as trees produced in the field (7, 11). The current study shows greater regenerated root weight on fabric-grown trees for two of the three species tested. However, there are data showing that 2.5 cm (1 in) caliper trees transplanted from fabric containers require more frequent irrigation during the first several months following transplanting than those planted from containers or from the field (11). According to the manufacturer, in most situations, trees transplanted from fabric containers also require staking for several months to anchor the tree until roots regenerate sufficiently to stablize it. In some situations, trees transplanted from containers or from the field may also need staking.

Landscape installation and management firms which practice sound horticultural principles should have little trouble establishing trees grown in fabric containers, in the field or in plastic containers. Remember that all trees have certain requirements for growth and development after planting, and that disregard for these will result in poor performance or plant death. Proper water management is the most important factor in controlling successful transplanting of trees grown in any production system. Each site has unique characteristics which should govern management practices. Trees are living organisms and cannot often be managed on a prescribed formula. Treat them accordingly and you will be successful transplanting trees to the often stressful urban environment.

Literature Cited

1. Anonymous. 1986. American Standard for Nursery Stock. American Assoc. Nurserymen, Wash. D.C.
2. Blessing, S.C. and M.N. Dana. 1987. *Post-transplant root expansion in Juniperus chinensis L. as influenced by production system, mechanical root disruption, and soil type.* J. Environ. Hort. 5(4):155-158.
3. Burdett, A.N., D.G. Simpson, and C.F. Thompson. 1983. *Root development and plantation establishment success.* Plant and Soil 71:103-110.
4. Coutts, M.P. 1983. *Development of the structural root system of Sitka spruce.* Forestry 56:1-16.
5. Dumbroff, E.B. and D.P. Webb. 1978. *Physiological characteristics of sugar maple and implications for successful planting.* For. Chron. 54(2):92-95.
6. Fuller, D.F. and W.A. Meadows. 1987. *Root and top growth response of five woody ornamental species to fabric field-grow™ containers, bed height, and trickle irrigation.* Proc. Southern Nurseryman Assoc. Res. Conf. 32:148-153.
7. Fuller, D.F. and W.A. Meadows. 1988. *Influences of production systems on root regeneration following transplanting of five woody ornamental species.* Proc. Southern Nurseryman Assoc. Res. Conf. 32:148-153.
8. Gilman, E.F. 1988. *Tree root spread in relation to branch dripline and harvestable root ball.* HortScience 23:351-353.
9. Gilman, E.F. 1989. *Plant form in relation to root spread.* J. Environ. Hort. 7:88:90.
10. Gilman, E.F. and M.E. Kane. 1990. *Growth and transplantability of Magnolia grandiflora following root pruning at several growth stages.* HortScience 25:74-77.
11. Harris, J.R. 1990. Effect of production method on pre-transplant growth and post-transplant establishment of four species of ornamental trees. M.S. thesis. University of Florida, Gainesville, Florida.
12. Ingram, D.L., U. Yadav, and C.A. Neal. 1987. *Production comparisons for selected woody plants in Florida.* HortScience 22(6):1285-1287.
13. Ingram, D.L., C.A. Martin, and B. Castro. 1988. *Container spacing strategies modify temperature and holly*

growth. Proc. Southern Nurseryman Assoc. Res. Conf. 33:71-74.
14. Kozlowski, T.T. and W.J. Davies. 1975. *Control of water balance in transplanted trees.* J. Arboric. 1(1):1-10.
15. Lumis, G.P. and S.J. Johnson. 1980. *Transplanting method influences survival and growth of bare-root coniferous nursery stock.* J. Arboric. 6(10):261-268.
16. Reiger, R. and C.E. Whitcomb. 1983. *A root control system for growing trees in the field.* Proc. Southern Nurseryman Assoc. Res. Conf. 28:100-102.
17. Richie, G.A. and J.R. Dunlap. 1980. *Root growth potential: its development and expression in forest tree seedlings.* N.Z. J. For. Res. 10:218-248.
18. Stone, E.C. 1955. *Poor survival and physiological condition of planting stock.* For. Sci. 1(2):90-94.
19. Stone, E.C. and G.H. Schubert. 1959. *Root regeneration by Ponderosa pine seedlings at different times of the year.* For. Sci. 5:322-332.
20. Tilt, K., W.T. Witte and H. Dickerson. 1988. *Effects of irrigation on growth of four ornamental trees produced in 'grow bags' and by traditional field production methods.* Proc. Southern Nurseryman Assoc. Res. Conf. 33:114-119.
21. Vanstone, D.E., and W.G. Ronald. 1981. *Comparison of bareroot verses tree spade transplanting of boulevard trees.* J. Arboric. 7(10):271-274.
22. Watson, G.W. 1985. *Tree size affects root regeneration and top growth after transplanting.* J. Arboric. 11(2):37-40.
23. Watson, G.W. and E.B. Himelick. 1982. *Seasonal variation in root regeneration of transplanted trees.* J. Arboric. 8(12):305-310.
24. Whitcomb, C.E. 1985. *Innovations and the nursery industry.* J. Environ. Hort. 3:33-38.

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ABSTRACTS

KLETT, J.E. 1990. 1900 **Crabapple evaluations.** Colorado Green 6(3):16-17.

Colorado State University is one of 20 cooperating sites evaluating about 60 different crabapple taxa for disease resistance and ornamental characteristics. Data from each of the sites are tabulated and summarized at the Morton Arboretum in Lisle, Illinois. Eventually, a national publication will be published featuring this information. Six clones appear to have good ornamental characteristics and fairly good disease resistance in Colorado: Centurion, David, Hennengi, Indian Summer, Prairiefire, and Velvet Pillar.

DOUGHTY, S.C. 1990. **Pruning properly.** Am. Nurseryman 171(1):103-104, 110, 112, 114, 116.

Proper pruning in the nursery is important because trees are unlikely to receive it in the landscape. Most homeowners and commercial landscape owners or managers don't know how to prune or train their trees. Selecting excurrent trees when possible saves labor in the nursery. Excurrent trees have tall, straight central leaders and need only minimal pruning. Decurrent trees have weak central leaders, and their lateral branches grow as fast as, or sometimes faster than, the terminal shoot. These trees often develop codominant leaders that create a multitude of V-shaped crotches and, consequently, many structural weaknesses. Pruning creates wounds. Genetically superior trees are better able to surround wounds with chemical barriers to limit the spread of decay. Selecting superior cultivars will allow your nursery to grow more serviceable, attractive trees that can be pruned with less chance of decay. After planting, the primary objective is to encourage the tree to become root-established as soon as possible. Research suggests that shoot pruning decreases root growth. Remove any basal suckers, epicormic shoots and crossover branches.