Nursery Production Method Affects Root Growth[1]

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Abstract

This study compared growth and biomass distribution on two commonly grown trees produced in plastic containers with those in fabric containers and in the field. Shoot:root ratio on field-grown and fabric container-grown laurel oak (*Quercus laurifolia* Michx.) was higher than on holly (*Ilex* x *attenuata* Ashe. 'East Palatka'). Ratios were similar for trees grown in plastic containers. Compared to oaks, a larger portion of holly root balls was comprised of small diameter roots. Root spread of field-grown laurel oak was similar to those produced in fabric containers. Trees of both species growing in plastic containers had several times more fine root mass (roots 2 mm or less diameter) within the root ball than those dug from the field or fabric containers. Total root ball root weight in plastic containers was less than in field- and fabric container grown trees. Root weight inside the root balls for field-grown and fabric container-grown trees was similar but field-grown root balls were twice the volume. Only 17% (field) and 26% (fabric containers) of holly root weight within the root ball was from roots 10 mm or less in diameter. However, 48% percent of root weight on trees grown in plastic containers was in this diameter class. Between 68 and 84%, depending on species and production method, of total-tree root weight was inside the root ball. Between 10% and 18.1%, depending on species and production method, of roots 2 mm or less in diameter was inside the root ball.

Index words: B&B, fabric container, field-grown, plastic container, root system.

Species used in this study: East Palatka holly (*Ilex* x *attenuata* Ashe. 'East Palatka'); laurel oak (*Quercus laurifolia* Michx.).

Significance to the Nursery Industry

Laurel oak and East Palatka holly trees grown above ground in plastic containers had several times the fine root mass (roots < 2 mm diameter) in the root ball but much less total root mass than those grown in a field nursery, or those from fabric containers. Together with the smaller root ball of container-grown trees compared to field grown trees of comparable size, this increase in small-diameter root mass may help account for rapid water loss from plastic container root balls reported previously. This could help explain why trees planted from plastic containers establish slower than those from a field nursery. Field-grown and fabric container-grown trees had nearly identical root mass inside the balls, though the standard root ball on field grown trees is twice the volume. This likely accounts for the increased water stress on trees transplanted from fabric containers.

Introduction

Contractors, arborists, landscape architects and horticulturists often have a choice to purchase trees that were produced in a variety of production methods. Many methods have been tried by growers recently including fabric containers and other in-ground systems and numerous above-ground systems (2). Few comparisons have been made of root systems within the root balls.

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 field soil or in plastic containers, but there was no difference among production methods for five other species (15). Fuller and Meadows (9) reported that for four of five species tested, root weight within the root ball was greater in fabric containers than in the traditional field-grown root ball. However, Chong et al. (7) reported reduced root weight in the fabric container root ball compared to trees grown directly in field soil. Harris and Gilman (12) showed that despite similarities in root ball weight, root surface area of plastic container-grown East Palatka holly (*Ilex* x *attenuata* 'East Palatka') was more than twice that of trees grown in fabric containers or directly in field soil. This was attributed to the greater surface area per unit length on the smaller diameter roots in the plastic container than on the larger ones found in field-and fabric container-grown trees.

The objective of this study was to compare growth and biomass distribution (roots and shoots) on two commonly grown trees produced in plastic containers with those in fabric containers and in the field.

Materials and Methods

In November 1987, 90 uniform 3.7 liter (1 gal) liners each of Laurel oak (*Quercus laurifolia*) and East Palatka holly (*Ilex* x *attenuata* 'East Palatka') about 1 m (3 ft) tall were planted into three production systems: plastic containers (PC), fabric containers (FC) and field grown (FG). Thirty of each were planted into 57 liter (15 gal) plastic containers (PC) [44 cm (17 in) wide at top by 40 cm (16 in) tall] using a pine bark:peat:sand (55:36:9 by vol) media. Another 30 liners of each species were planted into 36 cm (14 in) fabric containers (FC) (Gro-bags, Root Control, Stillwater, OK) spaced 1.8 m (6 ft) apart in field soil and backfilled with native soil (Astatula, excessively drained fine sand). The remaining 30 trees of both species were field grown (FG) without a fabric container (FG). Trees were grown for 2 years at Cherry Lake Tree Farm, Groveland, FL, with irrigation and fertilizer practices consistent with commercial nurseries in the area. Irrigation was delivered to the base of each tree with a low volume system for a period of 6 months after planting. For the remainder of the production period, irrigation was applied in a uniform, solid band down each row of trees. Trees were not root pruned during the study. Trees

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Table 1. Growth of field grown (FG), fabric container grown (FC), and plastic container grown (PC) laurel oak and East Palatka holly.[z]

	Laurel oak			East Palatka holly		
	Field	Fabric container	Plastic container	Field	Fabric container	Plastic container
Height (m)	3.62a	3.54a	3.24a	1.85a	1.74a	1.98a
Trunk diameter (cm)[y]	5.6a	5.3a	3.6b	4.1a	3.7b	3.0c
Maximum root extension from trunk (cm)	147.1a	143.8a	7.6b	84.16a	72.4b	0.0c
Root dry weight within root ball (g)	1279.7a	1269.3a	554.3b	837.2a	783.5a	441.7b
Total dry weight of root system (g)	1563.4a	1511.2a	554.3b	1228.4a	963.6b	441.7c
Shoot dry weight (g)[w]	5889.5a	3752.3b	1486.0c	1473.2a	1191.9ab	996.5b
Shoot:root (roots inside root ball) dry weight ratio	4.60a	2.96b	2.68b	1.76ab	1.52b	2.26a
Shoot:root (total root system) dry weight ratio	3.77a	2.48b	2.68b	1.20b	1.24b	2.26a

[z]Each value in table is mean of 5 trees. Means followed by different letters are significantly different within a species based on Duncan's Multiple Range test at $p < 0.05$.

[y]Trunk diameter measured at 15 cm from soil line.

[w]Total of trunk, shoots, branches, and leaves.

of each species were of typical commercial size for their age.

In January 1990, 5 trees were chosen at random from each production method and cut apart to determine total biomass distribution. Five FG trees of each species were dug with a tree spade adjusted to make a root ball diameter [about 70 cm (28 in) diameter] in accordance with American Association of Nurserymen standards (1). Five FC trees were dug by hand and the fabric was removed. Five PC trees were also chosen for root study. Roots within the root ball on FG and FC trees were washed free of soil and container media and separated from those growing outside the root ball.

Roots located outside the root ball were sampled by excavating a wedge defined by a 45 degree angle from the tree trunk (12.5 % of total soil area around the tree) on the north and south side of each tree. The wedge was extended as far from the trunk and as deep as needed to capture all tree roots growing outside the root ball in this wedge. Soil was washed from roots with water through a 4 mm (0.16 in) screen. Freshly dug roots were stored at 4C (38F) until they could be separated into diameter classes as follows: 0–1 mm, >1–2 mm, >2–5 mm, >5–10 mm and >10 mm and root dry weight determined. Root weights were multiplied by four to obtain total-tree root weight outside the root ball. The straight-line distance from the trunk to the farthest root tip was recorded as maximum root extension on each tree. Tree heights and trunk diameter at 15 cm (6 in) above soil line were recorded when trees were excavated. The entire top of the tree (leaves, branches and trunk) was dried at 70C (158F) to constant weight.

Results and Discussion

Laurel oak height, root dry weight and maximum root extension were similar for FG and FC trees (Table 1). Trunk diameter, and root and shoot dry weight were smaller for PC trees. This may have been due to the closer spacing of the container trees during production or because of water stress imposed by the limited media volume in a container. This has been noted for red maple (*Acer rubrum*), live oak (*Quercus virginiana*) and winged elm (*Ulmus alata*) (3, 5) and may occur for other species. Maximum root extension on most trees was more than twice the distance between the trunk and edge of the canopy (data not shown). East Palatka height was similar for each production method. Trunk diameter, maximum root extension and total root dry weight were significantly different for each treatment, least for PC, greatest for FG trees. (Table 1). Root ball weight on FG trees was similar to that on FC trees. Maximum root extension beyond the root ball soil was of course 0 for PC trees.

Shoot:root ratios on holly were largest on PC trees; ratios on oak were largest on FG trees. Shoot:root ratios on all production methods were less than half than previously reported on East Palatka holly (12). Trees in the current study were older and were in 57 liter (15 gal) containers; whereas, those in the previous study were grown for just 15 months in 35 liter (10 gal) containers. It has been previously reported that older plants have a lower shoot:root ratio than young nursery trees (11).

Trees of both species growing in PC had several times more fine root mass (0–1 mm and >1–2 mm diameter classes) within the root ball than those in the field (FC and FG) (Table 2). There was no difference among production methods in laurel oak root mass within the root ball in the >2–5 mm or >5–10 mm (>0.2–0.4 in) diameter classes. East Palatka holly in FC had more root weight inside the root ball in the >5–10 mm (>0.2-0.4 in) diameter class than FG or PC trees. For both species, the greatest root mass inside the root ball was in the >10 mm (0.4 in) diameter class. Both species in PC had less root weight in this class than FG or FC trees. Most root mass in FG and FC trees outside the root ball was in roots 10 mm (0.4 in) or less in diameter.

FG and FC oak trees had nearly identical root weights inside the root balls though FC root balls were half the volume of field grown root balls. Except for the >5–10 mm (>0.2–0.4 in) diameter class, holly FG and FC root weight inside the root balls were also nearly identical. This might indicate that they would transplant similarly, however Harris and Gilman (12) found that without frequent irrigation after transplanting, trees from FC were more stressed than FG trees. This was attributed to the smaller soil volume in the fabric container root ball. However, Hensley (14) found that in a finer textured soil trees from fabric containers grew similar to B & B trees for at least 3 years after transplanting. Beeson and Gilman (4) later showed in a sandy soil that with frequent irrigation trees transplanted equally well from FG or FC. Frequency of irrigation appears to impact the response of tree production method to transplanting.

Table 2. Dry weight of roots inside and outside of root ball within root diameter classes for field grown (FG), fabric container grown (FC), and plastic container grown (PC) laurel oak and East Palatka holly.[z]

Root diameter class (mm)	Root dry weight (g)									
	Laurel oak					East Palatka holly				
	Field		Fabric container		Plastic container	Field		Fabric container		Plastic container
	Inside	Outside	Inside	Outside	Inside	Inside	Outside	Inside	Outside	Inside
0–1	7.16	49.77*	8.26	78.40*	40.85	10.98	77.49*	16.01	71.86*	60.64
>1–2	7.32	50.91*	7.12	59.98*	25.23	9.64	40.61*	8.22	38.07*	26.26
>2–5	36.80	71.98*	39.07	80.94*	57.27	35.78	104.69	46.79	56.35	56.73
>5–10	103.69	61.33	91.98	22.53*	72.07	91.73	95.01	137.67	13.89*	74.62
>10	1124.7	49.70*	1122.9	0.00*	358.86	689.02	73.42*	574.77	0.00*	223.41
Total	1279.7	283.69	1269.3	241.86	554.29	837.15	391.22	783.45	180.17	441.66

[z]Each value in table is mean of 5 trees.

*Means for roots inside and outside of root ball are significantly different within this species and production method by paired comparisons *t* test at $p < 0.05$.

Only 17% (FG) and 26% (FC) of the total root weight within the root ball for holly was from roots 10 mm (0.4 in) or less in diameter. However, a much larger (Chi Square $p < 0.05$) percentage (48%) of total root weight from PC trees was in this diameter class. This large difference in distribution of root sizes within the root ball has been reported previously for smaller East Palatka holly (12). In that study, greater root surface area and weight for PC trees may have minimized post-transplanting water stress compared to freshly dug FG and FC trees. In addition, field-grown holly (8) and oak (17) species with greater small-diameter root weight in the root ball were found to transplant better than those with less fine diameter root weight. However, other studies showed that root pruned field grown Live oaks (*Quercus virginiana*) were less stressed after planting than comparably sized transplanted plastic container-grown trees even though container-grown trees had more small diameter roots (Gilman, unpublished). Root pruning may increase the amount of small diameter roots in the root ball or prepare the tree for transplanting in another unknown way. More research is needed to determine the impact of root pruning field grown trees on transplant survival and stress.

East Palatka holly had more roots in the smaller diameter classes than laurel oak (Table 2). Whereas roots 10 mm (0.4 in) or less in diameter accounted for 48% of root weight on container grown holly, only 35% of root weight was in this class for container grown oak. In contrast, roots 10 mm (0.4 in) or less accounted for 17% (FG) or 26% (FC) of total root weight inside the root ball of holly, but only 12% for FG and FC oak. Despite greater small diameter root mass, East Palatka holly established slower than laurel oak (6).

Most small-diameter [roots 5 mm (0.2 in) in diameter or less] root weight on both species was found outside the root ball on FG and FC trees. For example, only 14% (FG) and 10% (FC) of the dry weight of oak roots 1mm or less in diameter was inside the root ball. Twelve (FG) and 18% (FC) of the dry weight of holly roots 1 mm or less in diameter was inside the root ball. All roots larger than 10 mm were confined to the root ball in FC trees. Ninety-five percent (oak) and 90% (holly) of dry weight of roots >10 mm (> 0.4 in) was inside the root ball on FG trees. As a result, between 68% (FG holly) and 84% (FC oak and holly) of total-tree root weight (all diameter classes combined) was inside the root ball. There were no differences (Chi Square $p < 0.05$) between FG and FC trees in the percentage of total-tree root weight harvested in the root ball.

Previous estimates of the percentage of total-tree root length harvested within the root ball on trees not root pruned during production range between 2% and 8%, depending on species (10, 18). This appears to contrast sharply with the current study where more than 68% of total-tree root dry weight was harvested within the root ball of field grown oak and holly. However, root length and weight are two entirely different root attributes. Most root length on trees is derived from roots with a small diameter (16). Within a diameter class root length and weight are highly correlated (12). Most (86%, oak; 88%, holly) small diameter (<1 mm) root weight on trees in the current study was outside the root ball. Therefore, most root length was probably left outside the root ball.

It is clear that trees regularly survive the transplanting process with only a fraction of their small diameter roots but with most of their large diameter roots intact within the root ball. Perhaps the large diameter roots are more important to the recovery process than given credit and this issue needs further investigation. Maybe we should encourage production strategies that retain as much of the medium and large diameter roots as possible. After all, small diameter roots have a short life span (several weeks) and are regularly shed from the root system (13).

Literature Cited

1. American Association of Nurserymen. 1990. American Standard for Nursery Stock.

2. Appleton, B.L. 1994. Elimination of circling tree roots during nursery production. pg. 93–97 *In*: Proc. The landscape Below Ground. Intern. Soc. Arboric. Savoy, IL.

3. Beeson, R.C., Jr. 1992. Restricting overhead irrigation to dawn limits growth in container-grown woody ornamentals. HortScience 27:996–999.

4. Beeson, R.C, Jr. and E.F. Gilman. 1992. Diurnal water stress during landscape establishment of slash pine differs among three production methods. J. Arboriculture 18:281–287.

5. Beeson, R.C., Jr. and J. Haydu. 1995. Cyclic micro-irrigation in container-grown landscape plants improves plant growth and water conservation. J. Environ. Hort. 13:6–11.

6. Beeson, R.C., Jr. and E.F. Gilman. 1996. Production method affects tree establishemnt in the landscape. J. Environ. Hort. 14:81–87.

7. Chong C., G.P. Lumis, R.A. Cline, and H.J. Reissman. 1987. Growth and chemical composition of *Populus deltoides* x *nigra* grown in field-gro containers. J. Environ. Hort. 5:155–158.

8. Fare, D.C., C.H. Gilliam, and H.G. Ponder. 1985. Root distribution of two field-grown Ilex. HortScience 10:1129–1130.

9. Fuller, D.F. and W.A. Meadows. 1987. Root and top growth response of five woody ornamental species to fabric field-gro containers, bed height and trickle irrigation. Proc. Southern Nurserymen Assoc. Res. Conf. 32:148–153.

10. Gilman, E.F. 1988. Tree root spread in relation to branch dripline and harvestable root ball. HortScience 23:351–353.

11. Gilman, E.F. and M.E. Kane. 1991. Growth dynamics following planting of cultivars of Juniperus chinensis. J. Amer. Soc. Hort. Sci. 116:637–641.

12. Harris, J.R. and E.F. Gilman. 1993. Production method affects growth and post-transplant establishment of 'East Palatka' holly. J. Amer. Soc. Hort. Sci. 118:194–200.

13. Hendrick, R.L. and K.S. Pregitzer. 1992. The demography of fine roots in a northern hardwood forest. Ecology 73:1094–1104.

14. Hensley, D.L. 1993. Harvest method has no influence on growth of transplanted green ash. J. Arboriculture 11:379–382.

15. Ingram, D.L, U. Yadav, and C.A. Neal. 1987. Production comparisons for selected woody plants in Florida. HortScience 22:1285–1287.

16. Jensen, P. and S. Petterson. 1977. Effects of some internal and environmental factors on ion uptake in roots of pine seedlings. Swed. Conifer. For. Proj. Tech. Rep. 6:1–19.

17. Struve, D.K., T.D. Sydnor, and R. Rideout. 1989. Root system configuration affects transplanting of honeylocust and English oak. J. Arboriculture 15:129–134.

18. Watson, G.W. and E.B. Himelick. 1982. Root distribution of nursery trees and its relationship to transplant success. J. Arboriculture 13:126–130.

Evaluating Pulp and Paper Sludge as a Substitute For Peat Moss in Container Media[1]

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Abstract

Pulp and paper sludge from a newsprint mill was composted for 6 weeks and evaluated as a substitute for peat moss in container media. One-year-old seedlings of lilac (*Syringa vulgaris* L.) and amur maple (*Acer tataricum* L. ssp. *ginnala* (Maxim.) Wesm.) as well as rooted cuttings of cistena plum (*Prunus* x *cistena* Hansen) were planted in #1 plastic pots that contained a pine bark and sand mixture (2:1 by vol) or pine bark and sand amended with either 25% or 50% peat moss or composted paper sludge. A 75% compost medium that consisted of composted paper sludge and sand (3:1 by vol) was also used in the study. Plant height was measured every 4 weeks. After 14 weeks of growth, shoot dry weight and final plant height were measured. All plants in compost-amended media grew as well as or better than those in peat-amended media, regardless of the species grown. Lilac plants in 25% compost produced almost double the amount of shoot dry weight and were 80% taller than plants in the bark:sand or 25% peat media. Maple plants in 50% compost produced at least 33% more shoot dry weight than those in either peat-amended medium. Plum cuttings in 25% compost grew at least 53% taller than those in either peat-amended medium. These results demonstrated that composted paper sludge from newsprint production was a worthy substitute for peat moss in a container medium for the three species tested.

Index words: substrate amendment, potting mix, compost, newsprint sludge.

Species used in this study: common lilac (*Syringa vulgaris* L.); amur maple (*Acer tataricum* L. ssp. *ginnala* (Maxim.) Wesm.); and cistena plum (*Prunus* x *cistena* Hansen).

Significance to the Nursery Industry

Peat moss is an important component in soilless potting media, and its price can vary from \$77 to \$154 per m³ (\$60 to \$120 per yd³) depending on the grade and quantity ordered. This expense has forced growers to seek other sources of organic amendments. Nursery stock producers need organic amendments that resist decomposition, provide proper aeration and water-holding capacity, are nontoxic to plants and people (workers and customers), and support plant growth. Our study has shown that plants grown in media amended with up to 75% composted paper sludge grew as well as or better than plants grown in peat-amended media. Although most chemical and physical characteristics of compost-amended media were suitable, cation exchange capacity and water-holding capacity of these media need to be checked before planting.

Pulp and paper sludge from a particular paper mill should be relatively consistent during the year, providing growers with a possible low cost amendment. In fact, since the paper industry has a sludge disposal problem, nurseries may receive the material for free or be paid to take it. Sludges vary from mill to mill and have different characteristics depend-

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