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Production Method Affects Tree Establishment in the Landscape[1]

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Abstract

Trunk growth rates one year after transplanting 5 cm (2 in) caliper laurel oak (*Quercus laurifolia* Michx.) from above-ground plastic containers, from in-ground fabric containers or from the field (B&B) matched or exceeded growth rates before transplanting. Growth rates for all three treatments were similar seven months after transplanting. Shoots on field-grown trees grew more in the first year after transplanting than those from fabric or plastic containers. Roots removed at the time of digging were completely replaced on field and fabric container trees six months after transplanting. One year after transplanting, roots occupied the same soil volume as just prior to transplanting. Trees from plastic containers regenerated roots slower than B&B trees or those from fabric containers. When irrigation frequency was reduced 14 weeks after transplanting (WAT), trees from plastic containers were water stressed more (had more negative xylem potential) than B&B or fabric container trees. Growth rates of East Palatka holly (*Ilex* x *attenuata* Ashe. 'East Palatka') responded similarly to laurel oak; however hollies took longer to establish roots into landscape soil and took longer for the trunk growth rate to match that on trees prior to transplanting.

Index words: establishment rate, B&B, fabric container, field-grown, irrigation, planting, plastic container, root growth, transplanting.

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

Significance to the Nursery Industry

Provided trees are regularly irrigated after they are installed in a landscape, method of nursery tree production caused only a small difference in growth after transplanting. That is, trees from above-ground plastic containers were slightly shorter with smaller trunks than those from the field (B&B) or from fabric containers two years after transplanting. Trunk growth rates for all methods of production were nearly identical by 18 months after transplanting to the landscape. If irrigation is cut back too soon, trees from plastic containers appear to undergo more stress than field grown trees and would die first in an extended drought. This is probably due to the increased shoot:regenerated root ratio in the landscape on trees planted from plastic containers compared to B&B trees or those from fabric containers. On the other hand, if freshly dug trees from a field nursery are not irrigated regularly after transplanting, plastic container trees perform better in the months following transplanting (11).

Introduction

Contractors, arborists, landscape architects and horticulturists often have the choice of purchasing trees from a vari-

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ety of production methods. Many methods have been tried by growers recently, including fabric containers, other in-ground systems, and numerous above-ground systems (2). Few comparisons have been made of growth after transplanting.

Hensley (12) reported green ash (*Fraxinus pennsylvanica* Marsh.) trees transplanted into a clay soil in Kansas (USDA hardiness zone 5) from either in-ground fabric containers or bare-root grew as well as those with a traditional-sized B&B soil root ball (1). Harris and Gilman (11) showed that without daily irrigation after transplanting, freshly dug trees grown in fabric containers in the ground were more water stressed after harvesting and planting into sandy, well drained landscape soil than B&B trees or those from plastic containers. There was no difference in stress if trees were watered daily after transplanting.

Beeson and Gilman (4) noted that slash pine (*Pinus elliottii*) planted from above-ground plastic containers established slower in a sand soil in Florida (hardiness zone 9) than trees from fabric containers or field grown plants. The authors speculated that despite daily irrigation for 3.5 months after planting, slower root growth caused by a dry root ball may have slowed establishment of trees from plastic containers. The media comprising the root ball of trees in plastic containers dries out quickly, in some cases within several hours after irrigation (13). Harris and Gilman (10) demonstrated no difference in root growth 10 weeks after transplanting well-irrigated one-inch caliper laurel oak (*Quercus laurifolia*) from three production methods. In contrast, field grown slash pine regenerated less root weight than trees from fabric or plastic containers (4). Blessing and Dana (5) demonstrated greater root regeneration from plants installed from plastic containers; whereas in a followup study, field grown plants performed better (6). Because of the range of results from these studies, it is not surprising that growers and contractors continue to ask for more information about the production/post-planting transition period.

The objectives of this study were to compare post-transplant growth and establishment rate on trees planted into the landscape from plastic containers with those from fabric containers and B&B.

Materials and Methods

In November 1987, 30 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 57 liter (15 gal) black plastic containers (PC) using a pine bark:peat:sand (55:36:9 by vol) substrate. About 500 m away, 30 liners of each species were planted into 36 cm (14 in) fabric containers (FC) (Root Control bags, Root Control, Stillwater, OK) spaced 60 cm (2 ft) apart in field soil and backfilled with native soil (Astatula, excessively drained fine sand). An additional 30 trees of each species were field grown (FG) directly into the same soil without a fabric container. Trees were grown for 2 yr with irrigation and fertilizer practices consistent with commercial nurseries in central Florida. Irrigation was delivered daily to each tree with a low volume system except during periods of sufficient rainfall. For FG and FC trees, water was directed at the base of each trunk for a period of 6 months after planting. For the remainder of the production period, irrigation was applied in a uniform, solid band about 1 m (3 ft) wide down each row of trees. Trees were not root pruned during the study. Fertilizer was applied regularly through the irrigation system and supplemented with granular twice each year. Trunk diameter was measured at planting and at the end of the production period in January 1990.

In January 1990, 5 trees were chosen at random from each production method and species, and root systems inside and outside of the root ball were excavated and measured (9). Twenty FG trees of both species were dug with a three-shovel tree spade adjusted to make a root ball diameter [about 71 cm (28 in) dia] in accordance with AAN root ball diameter standards (1). Twenty FC trees were dug with shovels and the fabric removed. Some soil was lost from the root ball during this process. Twenty PC trees were removed from the plastic containers. Root systems of PC trees were not cut or disturbed in any manner. These 60 trees from both species were transplanted about 1 km (0.6 miles) away into a Astatula fine sandy soil used to grow FG and FC trees. All trees were out of the ground without irrigation for no more than two hours.

Trees were arranged 2 m (6 ft) apart in a randomized complete block design with one replicate of both species from each production method (6 trees) in each of 20 blocks. Planting holes for FG trees were the same size as the root ball because they were dug with the tree spade. Those for FC and PC trees were slightly wider than and just as deep as the root ball. No amendments were added to the backfill soil around the root ball. Due to wind exposure at the site, oaks were staked for about 6 months to anchor them in place.

Trees were irrigated daily after transplanting during the morning hours with 35 liter (9 gal) of water supplied through spray stakes (Aquaturret; Stuppy, Inc., N. Kansas City, MO). After 14 weeks, irrigation frequency was reduced to every other day and the volume increased to 58 liter (15 gal), except after a rain of at least 1.25 cm (0.5 in). Five FG trees not transplanted (controls) were irrigated every other day throughout the experiment with 58 liter (15 gal) per tree.

Nine, 28 and 50 weeks after transplanting (WAT), roots growing into the backfill and landscape soil were harvested from 3 trees of each species and production method. Once a tree's roots were sampled, that tree was removed from the study. All roots outside the original root ball within a wedge-shaped section defined by a 45 degree angle from the trunk on the north and south sides (for a total of one-quarter of the entire root system) of each harvested tree were excavated and removed. Soil was washed from roots with water through a 4 mm (0.16 in) screen. Freshly dug roots were stored at 3C (38F) for several days until they could be separated into diameter classes as follows: 0–1mm, >1–2mm, >2–5mm, >5–10mm, and >10mm. Roots were dried at 70C (158F) for several days until they reached a constant weight. 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 in each wedge-shaped section was recorded as maximum root extension.

Trunk diameter was measured 15 cm (6 in) above the soil at transplanting, and again in March and August 1990, January and July 1991 and January 1992. Length of 5 new shoots on each tree was measured in January 1991, one year after transplanting. Height of each tree was recorded at transplanting and one and two years later.

Shoot water potential was measured periodically during the 2 years following transplanting. On a weekly basis the first 12 WAT, water potential was recorded at two hour intervals (diurnally) starting before dawn (pre-dawn) until sunset on 3 trees of each treatment and species. Subsequently, measurements were made biweekly for three additional months then monthly for the remainder of the study. Water potential was measured before dawn (ending at 0630 to 0730 depending on the time of year) on control trees (not transplanted) each time it was measured on the transplanted trees, but diurnal measurements were taken on controls monthly. Water potential was measured with a pressure chamber (Model 3001, Soilmoisture Corp., Santa Barbara, CA) using compressed nitrogen increased at a rate of approximately 2.5 kPa/sec. Shoots were collected from the sunny side of the tree.

Cumulated water stress in MPa-hr (SΨ) was estimated for each diurnal curve by calculating the area above the curve to 0 MPa and then taking the absolute value. This permitted a quantification of water stress for each tree on a daily basis and simplified comparisons among treatments (3).

Main effects between production methods were tested with analysis of variance and means compared with Duncans multiple range test. Equality of slopes of regression lines were compared with the t-test.

Results and Discussion

Shoots on holly (15 cm) and oak (32 cm) transplanted from the field (FG) grew significantly more in the first year after transplanting than those from PC (12.5 cm holly, 25 cm oak) or FC (11 cm holly, 23.5 cm oak) although the difference was small. There was no shoot growth difference between PC and FC laurel oak. Although holly from FC produced the least amount of shoot growth ($P < 0.05$) in the first year after planting, shoots grew only 4 cm (0.16 in) less than FG trees.

Trunk cross-sectional area on both species increased at a slower rate ($P < 0.01$, t-test) on PC trees than on trees grown in field soil during the production phase of the study (Fig. 1). Trunk cross-sectional area in FC holly and oak increased less ($P < 0.05$, t-test) in the first year after transplanting than in the other two treatments (Fig. 1). By the end of the first year after transplanting, PC holly trunks increased in caliper more ($P < 0.05$) than FC trees by 5 mm (data not shown). There was no difference in oak trunk growth rate between PC and FG trees the first year after planting to the landscape; however, FC trees grew slower than FG trees. Except for PC oaks growing significantly slower than FC and FG trees, trunk growth rate in the second half of the second year after transplanting was nearly identical for all treatments (no significant difference, $P < 0.5$, t-test) on both species. Trunk area on trees planted from different production methods also grew at the same rate for pines (*Pinus elliottii*) (4) and green ash (*Fraxinus pennsylvanica*) (12) after planting to the landscape.

Except for FG oaks, the rate of trunk cross-sectional increase for FG and FC trees was slower during the first year after planting than before. This was expected because a portion of the root system was removed when the trees were

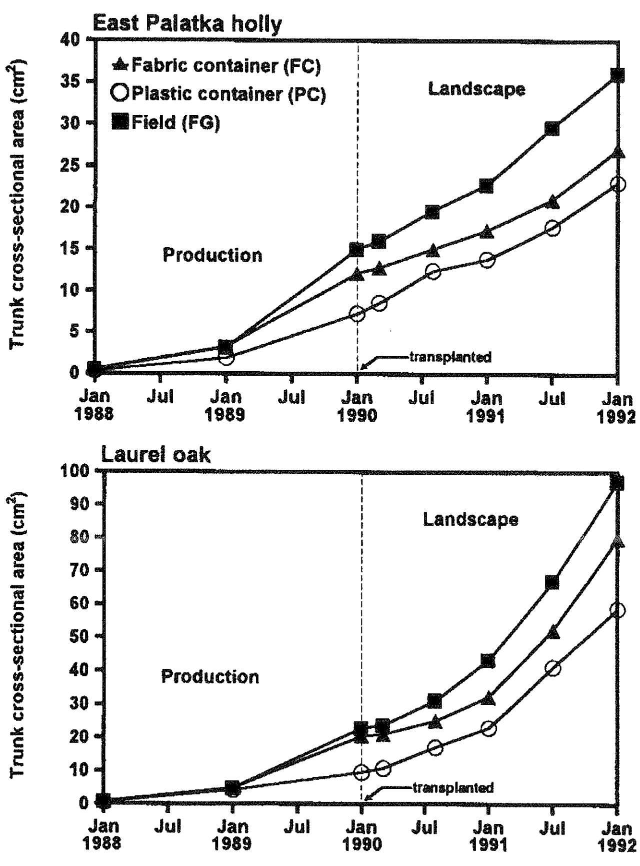

Fig. 1. Trunk cross-sectional area of trees produced in plastic containers, in fabric containers or in the field during production and after transplanting to a landscape.

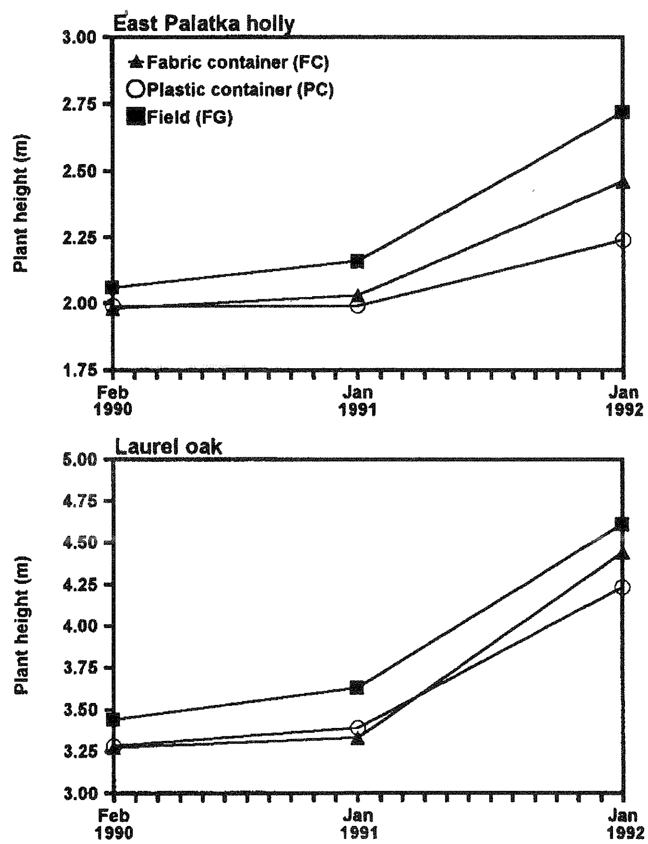

Fig. 2. Plant height for each production method at transplanting and one and two years later.

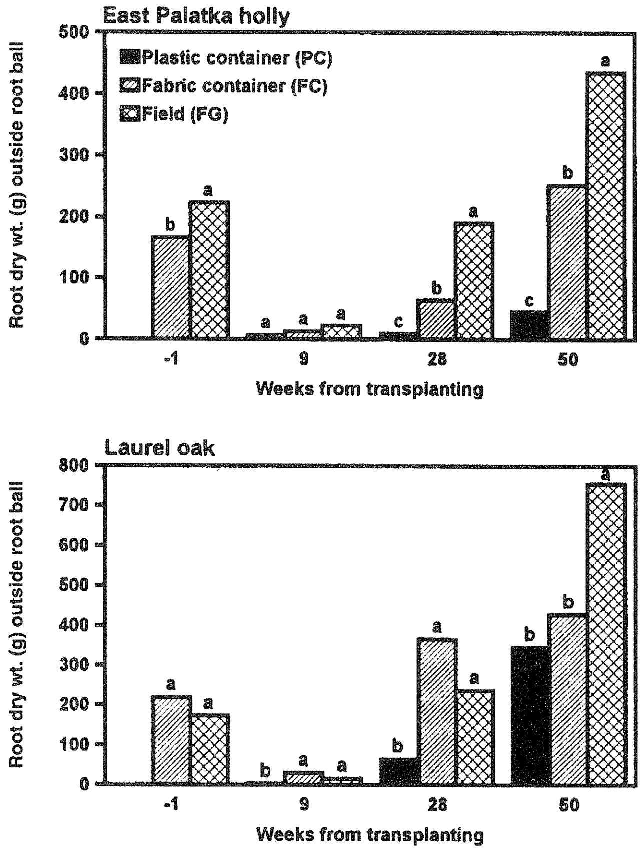

Fig. 3. **Root dry weight outside root ball for each production method one week prior to transplanting and 9, 28 and 50 weeks after transplanting. Means within a week with different letters are significantly different at $P < 0.05$ with Duncans multiple range test.**

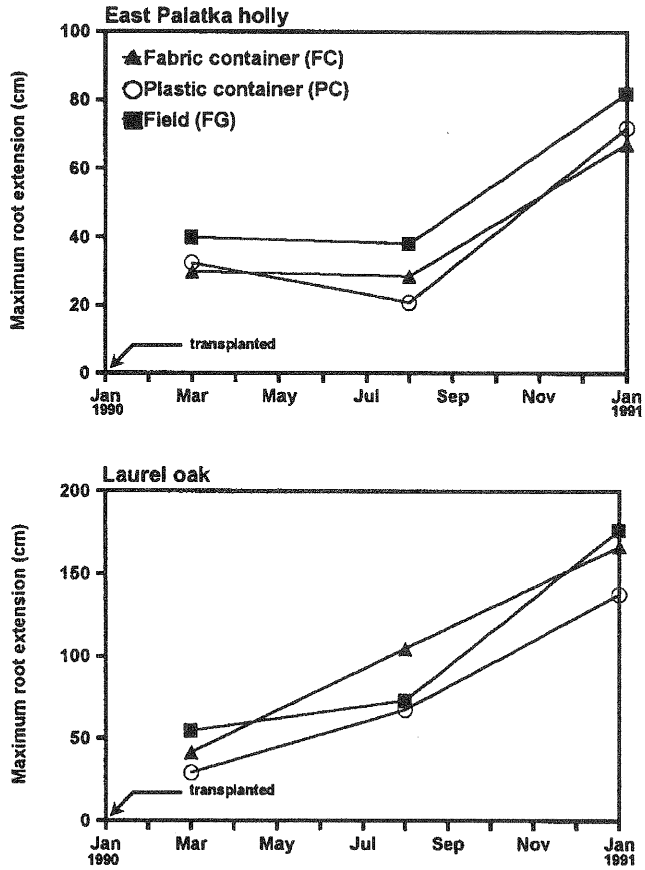

Fig. 4. **Maximum root extension 9, 28 and 50 weeks after transplanting.**

dug (9). Nine weeks (FG oaks), six months (FC oaks) and one year (FG and FC holly) after planting, trunk growth rate matched growth rate prior to transplanting (Fig. 1) indicating that trees were established (8, 14). PC trees grew faster after transplanting than in the nursery, perhaps because they were spaced too closely together or subject to regular water stress in the nursery environment. This is not uncommon (3).

Trunk growth rate slowed on PC holly trees in the second half of the first year after transplanting (Fig. 1) immediately following the time when daily irrigation was changed to every-other-day (late April 1990, 14 WAT). None of the other holly treatments nor the oaks appeared to be affected by reduced irrigation frequency, i.e. there was no reduction in trunk growth rate for these other treatments. Holly growth rate recovered in the second growing season after planting.

Trees in all treatments increased in height much slower in the first year than in the second year after transplanting (Fig. 2). This corresponded with the trunk growth rate which was faster the second than the first year after transplanting. Although trees in all treatments were the same height at transplanting, FG trees of both species were taller than PC trees two years after transplanting. FG trees were taller than FC only for holly.

Most regenerated roots were in the 0–5mm diameter class. Data from large diameter roots were similar therefore they are not shown. FG and FC oak regenerated more roots into the landscape soil 9 and 28 WAT than PC trees (Fig. 3). FG oaks had more roots in landscape soil than FC or PC trees 50 WAT. There were no differences in root regeneration among treatments for holly 9 WAT. However at 28 and 50 WAT, FG holly regenerated more roots than FC holly which regenerated more than PC holly.

By 28 WAT, regenerated root weight on FG and FC oaks was equal to or greater than the weight of roots removed from the tree at transplanting (week –1) (Fig. 3). However, maximum root extension did not equal that on trees just prior to transplanting until one year after transplanting. Holly required between 28 (FG) and 50 (FC) weeks for root weight to be completely replaced. Hollies appeared to be slower establishing than oaks. Root extension on holly did not change during the summer months for any treatment (Fig. 4) but density increased (Fig. 3); whereas root extension on oaks continued to increase through the season for all treatments (Fig. 4). It was apparent that compared to oak, holly roots increased in spread slowly during the first 6 months after transplanting.

Despite the more negative mean water potential on FC oaks especially in late morning, cumulated water stress ($S\Psi$) two WAT was statistically similar for all production methods but predawn water potential for FG oaks was significantly lower than the other two production methods (Fig.

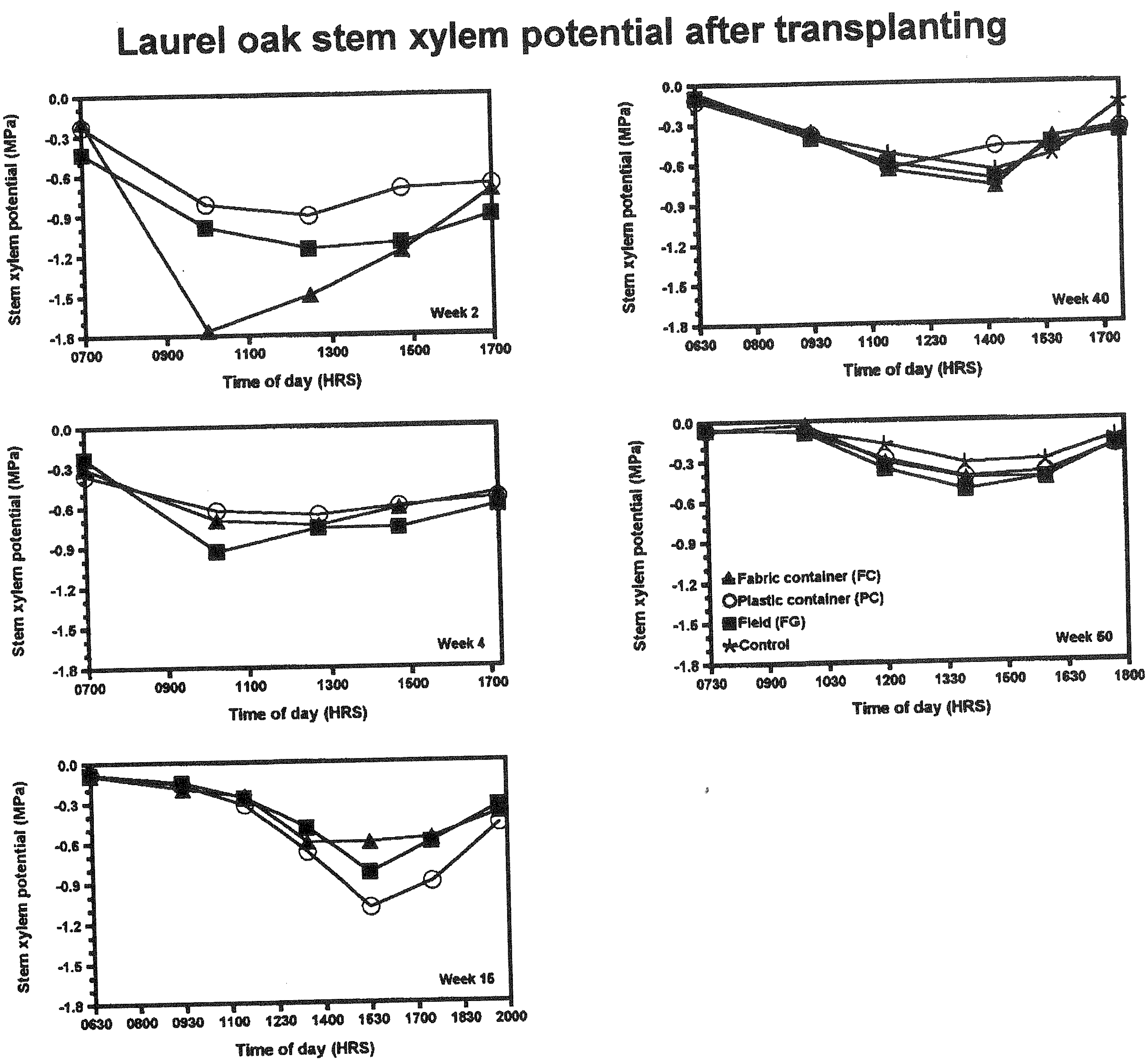

Fig. 5. Stem xylem potential 2, 4, 15, 40 and 50 weeks after transplanting laurel oak.

5). SΨ two WAT was significantly less for PC than for FG and FC hollies (Fig. 6) indicating greater stress on FG and FC trees. However the differences were small and probably of no biological significance. Two weeks later (week 4), predawn water potential was lower for PC holly indicating that these trees were more stressed than the other production methods, but again the difference was small. Perhaps more importantly, SΨ on PC holly remained consistently greater than FG and FC trees from 4 through 15 WAT. Apparently, applying irrigation once daily did not supply enough water to the roots to prevent stress from occurring. Lack of vigorous root growth in the first few months after planting PC holly may have resulted from greater water stress.

Diurnal water potential at week 15 was taken 12 days after irrigation was changed from daily to every other day. PC holly on this day showed a significant increase in water stress (greater SΨ) compared to the other production methods (Fig. 6). Mean SΨ at week 15 for PC oak (7.18 MPa-hr) appeared to be greater than the other production methods (5.35 MPa-hr for FG; 5.14 MPa-hr for FC) but the difference was only significant at $P < 0.23$. By 40 WAT there was no difference in SΨ between control oaks which were not transplanted and transplanted trees. This might be a good indication that trees were established. FG holly at 40 WAT had the same SΨ as control trees also indicating establishment; whereas PC and FC trees were slightly ($P < 0.05$) more stressed. Roots removed at transplanting on FG holly were nearly replaced by 28 WAT (Fig. 3) suggesting that these trees might be established but maximum root extension did not match that of holly just prior to transplanting until one year after transplanting (Fig. 4).

At 50 WAT all treatments on both species again had significantly higher SΨ than trees that were not transplanted, although the differences were small and probably not biologically significant. For example, laurel oaks maintain photosynthesis to about −1.2 MPa (Beeson, unpublished). The

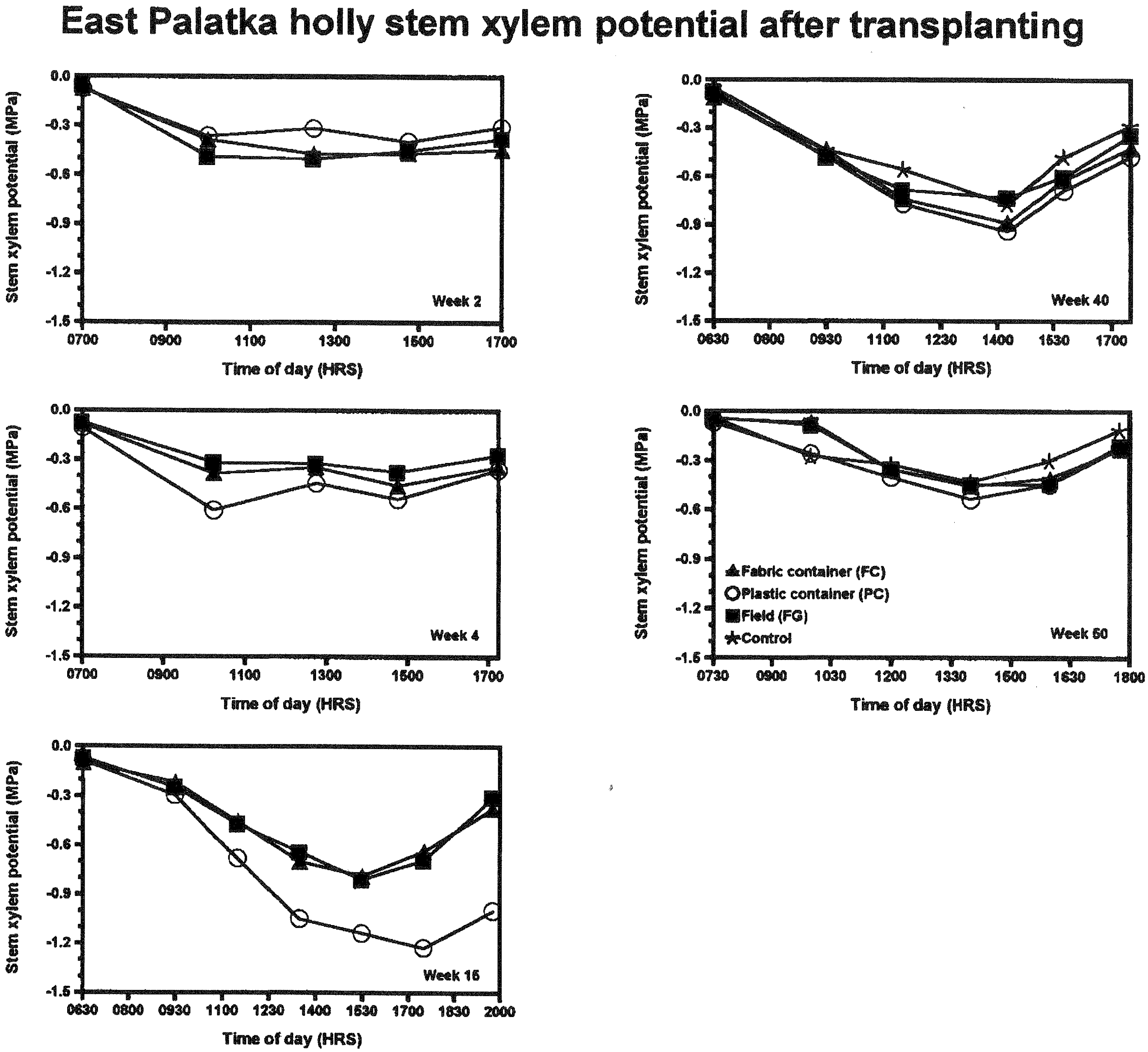

Fig. 6. **Stem xylem potential 2, 4, 15, 40 and 50 weeks after transplanting East Palatka holly.**

water potential was less than –0.6 MPa on all treatments. Combined with the oak root data which showed roots were entirely replaced by 28 WAT (Fig. 3), and the rate of trunk diameter increase, which 50 WAT matched the rate prior to transplanting (Fig. 1), oaks appear to have become established in the landscape somewhere between 28 and 40 WAT. This equates to about 14 to 20 weeks per inch (2.5 cm) trunk caliper [at 15 cm (6 in) above soil] if irrigated as in this study. Establishment would probably take longer if trees were irrigated less often as in most landscape sites. Pines took from 10 (field grown trees) to 12 (container grown trees) weeks per inch trunk caliper to establish in hardiness zone 9 under a similar irrigation regime (4). Trees in hardiness zone 5 take up to one year per inch caliper to establish (14).

Although root weight was replaced by 28 WAT FG and FC oaks (Fig. 3), roots were not as spread out (Fig. 4) as they were before transplanting (9). This increase in root density probably accounted for establishment taking longer than the time it took to replace the removed root system. In addition, the shoots had grown, thus the tree was larger than at transplanting. Soil dries quickly when root density is greater. Dry soil on days without irrigation may have prevented the rate of trunk diameter growth from reaching its full potential during the later part of the first year after transplanting. Perhaps the rate of trunk diameter growth would have reached its full potential if irrigation were continued daily for an entire year after transplanting. Although this might not be practical in most landscape situations, it suggests that growth rate after transplanting into well drained sandy soil can be manipulated by water management, even before trees are well established.

The trunk diameter growth:regenerated root dry weight ratio (mm:kg) 50 WAT trees from PC (266 holly, 54 oak) was far greater ($P < 0.05$) than the ratio for field (30 holly, 28 oak) or fabric container (28 holly, 23 oak) trees (Fig. 3). This increase in shoot:root ratio could make trees from plastic containers susceptible to drought injury in landscapes without an irrigation system. It also suggests that growth rate of trees from plastic containers might have been much slower if irrigation were discontinued before the termination of the study.

This and the companion study (9) show that trees grown in a field nursery either directly in soil or in fabric containers can lose more than 85% of their fine root weight (<2 mm diameter) and recover quickly if properly irrigated. This may be due to the large portion of total root weight harvested on trees from fabric containers or from a field nursery. A previous study (7) showed that less than 8% of the root system length on non root pruned field grown trees is harvested inside the root ball, leaving 92% or more in the nursery. Watson and Himelick (15) reported as little as 2% of the soil volume originally exploited by the root system is retained on a B&B tree. These studies measured either root length or soil volume exploited by roots, not root weight. Most length is in the small diameter roots. The current study shows that most small diameter roots are left in the nursery, whereas most large diameter roots and most of the root weight are harvested with the root ball. Because trees transplant as well B&B as from plastic containers, perhaps the small diameter roots are not very important to the transplanting process. If small diameter roots were important to transplant survival and growth, we would have expected the trees from plastic containers to far out-perform the FG and FC trees because PC trees had several times more small diameter root mass (9). We would also have expected hollies to establish faster than oaks since a greater portion of the holly root ball was comprised of small diameter roots. This did not happen.

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