EFFECTS OF PLANTING HOLE CONFIGURATION AND SOIL TYPE ON TRANSPLANT ESTABLISH-MENT OF CONTAINER-GROWN LIVE OAK

by Michael A. Arnold and Douglas F. Welsh

Abstract. Container-grown *Quercus virginiana* seedlings were transplanted to monoliths containing sandy or clay soil and to a field site employing five planting hole configurations of equal volume. Shoot growth and xylem water potentials were measured for 125 days following transplanting to monoliths. Roots of seedlings in the monoliths were excavated to determine root regeneration into the backfill and soil outside of the planting hole. Seedlings transplanted to the field were observed for an additional year. No planting hole configuration was markedly superior, but the sloped cylindrical holes might be advantageous in droughty sites. Root growth out of the rootball was not impeded by the media - backfill interface nor the backfill - planting hole interface regardless of soil type or planting hole configuration. Greater root growth occurred in clay soil. Sloped cylindrical planting holes slightly increased the caliper growth of seedlings in both monoliths and the field. Planting hole configurations did not affect xylem water potentials. Transplant establishment appeared to be completed by the autumn (125 days) following transplanting.

Media of container-grown plants dry quickly following planting or irrigation (3,4), thus regeneration of roots outside of the original rootball into the surrounding backfill and native soil is critical to establishment of transplanted trees. Roots must first elongate into the backfill soil during initial establishment and ultimately must penetrate into the soil outside the planting hole. This process may be hindered with container-grown trees by the contrast between the low bulk density of most commercial container media and the higher bulk density of many soils (5). Glazed surfaces and/or differences in soil bulk density at interfaces of planting holes have been reported to effectively containerize roots within the original planting hole (6, 8). More recent studies have found no significant impedance of root growth from amended or non-amended backfill soil into the surrounding soil, even on compacted clay sites (9, 10).

The angle at which a root encounters the in-terface between a less dense medium and a more dense soil may influence penetration or deflection, particularly if a glazed surface exists (5). Typical planting holes in landscapes are shaped when dug as cylinders or bowls. Watson et al.(9) found some increase in root growth with an increase in planting hole size. They also observed some improvement in the direction of root growth out of the planting hole by sloping the sides of the hole outward from bottom to top (9). The objectives of the following experiments were to determine the effects of differing soil types and planting hole configurations (of equal volume) on post-transplant establishment of container-grown live oak.

Materials and Methods

Container production. In March 1993, 85 *Quercus virginiana* seedlings were obtained from Greenleaf Nursery Co. (El Campo, Texas). Seedlings had been sown the previous fall in containers (Can-Am Containers, Springhill, NS, Canada) and ranged from 7 to 10 cm in height. Seedlings were planted in 2.3 liter containers (14 cm diameter, 15 cm tall cylindrical black plastic nursery pots, Lerio Corp., El Campo, TX) containing a 3 parts pine bark : 1 part coarse builders sand (vol.:vol., bulk density 0.68 g/cm^3) amended with 3.5 Kg dolomite/m^3, 1.75 kg gypsum/m^3, 0.86 kg Micromax trace elements (Sierra Chemical Co., Milpitas, CA)/m^3, and 1.75 kg 0N-20P-0K/m^3. Seedlings were placed on 75 cm tall benches in a greenhouse with day/night temperatures set at 22/16°C. Natural photoperiods were interrupted from 00:00 to 04:00 hr. using 40 watt incandescent bulbs suspended 1 m apart and 0.5 m above the benches. Sixteen g 18N-3.1P-8.3K-1Fe (18-7-10) 8-9 month slow release fertilizer (Sierrablen, Si-

erra Chemical Co., Milpitas, CA) were placed on the media surface of each container. Seedlings were watered as needed and fertigated weekly with 200 mg N/liter from a 24N-3.5P-13K (24-8-16) water soluble complete fertilizer (W.R. Grace Co., Fogelsville, PA). On 5 May 1993, seedlings were moved outdoors under 55% light exclusion. Irrigation and weekly fertigation continued as before. Seedlings were staked and trained to a central leader. On 19 May 1993, seedlings were moved to full sun and spaced 0.5 m apart.

Monolith comparisons. On 11 July 1993, 50 seedlings were transplanted to cylindrical (24 cm tall x 27 cm wide) soil monoliths enclosed in black plastic containers with five drainage wholes on the bottom. Twenty five of the monoliths were excavated from undisturbed (not cultivated for at least ten years prior to excavation) clay loam soil (Zack Series, Zack-urban land complex, fine, montmorillonitic, thermic udic paleustalfs, pH 7.8, bulk density 1.57 g/cm^3, 31 % sand, 31 % clay, 38 % silt). Only intact monoliths were used in the study. Cracked or fissured monoliths were discarded. The remaining 25 monoliths were composed of commercially dug Brazos river bottom soil (Silawa fine sandy loam, siliceous, thermic ultic haplustalfs, pH 6.6, bulk density 1.56 g/cm^3, 73 % sand, 9 % clay, 18 % silt), commonly sold as topsoil to local builders and homeowners. Containers filled with the Brazos topsoil had been exposed to natural rainfall for two months prior to planting.

Five different planting hole configurations (Fig. 1): cube, cylinder (with or without scarified sides), star, and sloped cylinder (inverted frustum of a cone), of equal volume (4860 cm^3) and depth (15 cm) were excavated in each of 10 monoliths, five per soil type. Surfaces of the cube, star and sloped cylinders were scarified by randomly scraping 0.2 to 0.5 cm into the sides of the planting hole with a trowel edge. Prior to scarification, a glazed surface was present on most clay planting hole surfaces, while sandy loam surfaces were not glazed. A light dusting of blue Strait-Line Marking Chalk (Irwin Co., Wilmington, OH) was applied to planting hole surfaces to facilitate demarcation of the planting hole at harvest.

Prior to planting, exterior surfaces of rootballs were sprayed with a 1% methylene blue in water
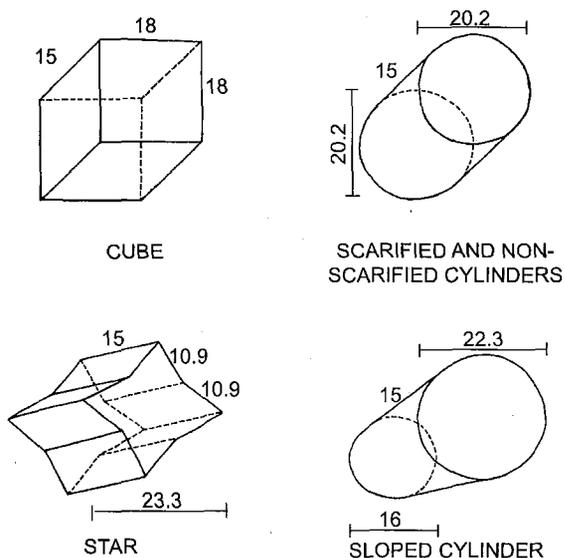
CONFIGURATIONS AND DIMENSIONS (cm) OF PLANTING HOLES

Figure 1. Configurations and dimensions (cm) of the planting holes for both monolith and field studies. Dashed lines indicate hidden portions of the three dimensional representations. Planting hole surfaces of the cube, star, sloped cylinders (inverted frustum of a cone) and half of the vertical walled cylinders were scarified at planting.

solution to assist in distinguishing roots present at planting from subsequently regenerated roots (1). At planting, seedling height and caliper (5 cm above the root collar) averaged 52 cm and 5.5 mm, respectively. Shoot and root dry weights averaged 9.42 g and 4.00 g, respectively, based on a subsample of five seedlings. Holes were backfilled with the excavated soil from each planting hole, the bulk density of clay backfill was 1.45 g/cm^3 and 1.35 g/cm^3 for the Brazos topsoil. Model 2725 Jet Fill Tensiometers (Soil Moisture Equipment Corp., Santa Barbara, CA) were inserted to a depth of 15 cm in the backfill soil and container media (two per monolith) in three monoliths of each soil type. An additional application of 16 g of slower release fertilizer was applied to the surface of the backfill soil. After planting, the exposed upper surfaces of the monoliths were covered

with a 3 cm deep mulch of composted pine bark. Monoliths were placed at 1 m x 1 m spacings on woven black polyester weed cloth covered gravel in a completely random design outdoors in full sun. Irrigation was applied every day or two during the first two weeks following transplanting and then tapered to twice weekly during the summer and once per week during the fall to supplement natural rainfall. At each irrigation event 1.5 liters of water/monolith was applied via spot spitters (Roberts Irrigation Products, San Marcos, CA) to provide an even wetting of the monolith surface.

Mid-day (12:30 - 14:00 hr.) and subsequent pre-dawn (04:00 - 05:30 hr.) xylem water potentials of 6 to 8 cm long lateral branch tips from three seedlings per treatment combination were measured using a PMS Model 610 pressure chamber (PMS Instrument Co., Corvallis, OR) at transplanting and 1, 21, 53, 83, and 125 days thereafter. Seedling height and caliper were measured and ambient atmospheric (10 cm above the soil surface), soil (1 cm interior to the south side of the monolith), and media (1 cm from the south side of the root collar) temperatures (expanded-range digital thermometer with stainless-steel triple-purpose probes, Fisher Scientific, Pittsburgh, PA) were recorded on the same days. After 125 days (15 November, 1993) roots were excavated from the monoliths. Dry weights (four days at 70°C) of shoots, roots inside the original rootball, roots outside the rootball but inside the planting hole, and roots extending beyond the planting hole were recorded.

Field test. On 17 July 1993, 30 seedlings were transplanted from 2.3 liter containers to a field plot (College Station, TX, Boonville Series, Boonville fine sandy loam, fine, montmorillonitic, thermic ruptic-vertic albaqualfs, pH 9.1, bulk density 1.51 g/cm³, 61 % sand, 11 % clay, 28 % silt) on 1 m within row and 3 m between row spacings in a randomized complete block design, five planting hole configurations x 3 blocks x 2 seedlings/block. Seedlings were planted as previously described, except root and soil dyes were omitted. Drip irrigation was provided daily for the first week, on alternate days the second week, biweekly the following four weeks and weekly thereafter when less than 1.5 cm of precipitation had occurred

since the previous irrigation. Three seedlings were equipped with tensiometers as described above. Height, caliper, and survival were recorded at planting and the end of the first and second growing seasons following transplanting to the field. Data for both experiments were analyzed using analysis of variance, and where appropriate, least squares means and Duncan's mean separation procedures (7).

Results and Discussion

Monolith comparisons. Survival was 100% in both monolith and field studies. Methylene blue and blue marking chalk provided good demarcation of planted rootballs and planting hole surfaces at 125 days after application. Seedlings grown in clay monoliths had greater ($P < 0.05$) shoot dry weight (40.89 g vs. 33.94 g), caliper (7.3 mm vs. 6.9 mm), total new root growth (10.82 g vs. 4.75 g) and root growth outside of the planting hole (Fig. 2) than those grown in sandy soil. Soil moisture tensions in sand and clay monoliths were similar at all sample dates and were more negative than -10 KPa on only days 21 and 83, suggesting that soil moisture was seldom limiting in the monoliths. Soil in monoliths tended to be more moist than the field soil, significantly ($P < 0.05$) so at 7, 53, and 125 days following transplanting. The mean maximum soil moisture tension in the field occurred at 53 days following transplanting (-21 KPa). Soil
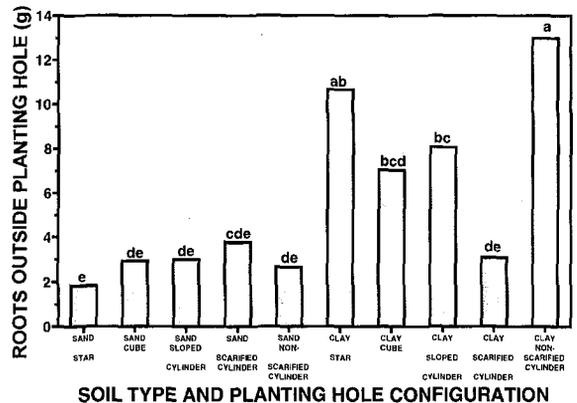

Figure 2. Root growth outside the planting hole at 125 days after transplanting for live oak seedlings grown in sand or clay monoliths with five planting hole configurations. Means with the same letters are not significantly different at P < 0.05.

moisture tension of the media was on average 3.1 KPa more negative ($P < 0.05$) than the surrounding backfill in monoliths or field soil. Greater water loss from container media than from the surrounding soil is well documented (4).

While statistically significant (P (0.05) main effects (Fig. 3) and interactions (Fig. 2 & 4) of soil type and planting hole configurations existed for growth parameters, relatively few generalizations could be drawn. Seedlings grown in sloped cylinders had greater caliper than those in all other configurations except scarified cylindrical holes in monoliths (Fig. 3A) and star-shaped holes in the field (Fig. 3B) regardless of soil type (data not shown). However, height growth (Fig. 4) was affected by both soil type and planting hole configuration with those seedlings grown in non-scarified clay cylinders growing less than seedlings in sandy soil with cube-shaped or non-scarified
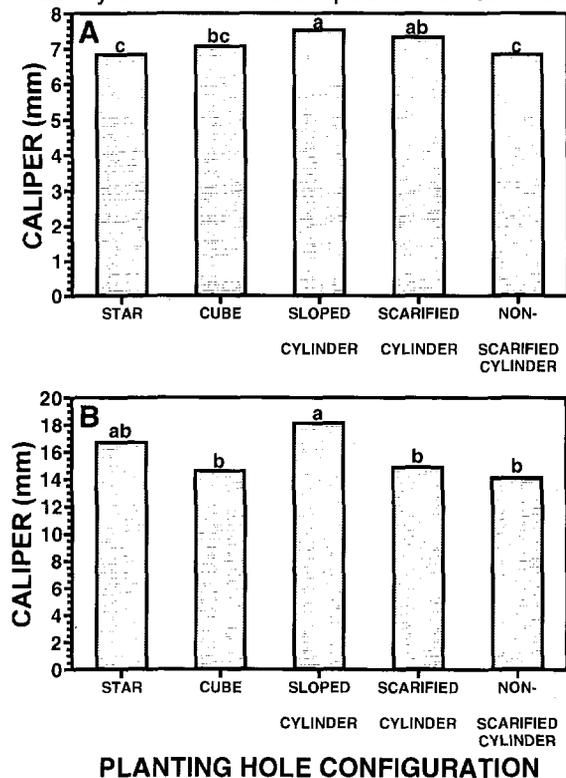
PLANTING HOLE CONFIGURATION

Figure 3. Effect of planting hole configuration on caliper of live oak seedlings grown for 125 days in soil monoliths (A) or after two growing seasons in the field (B). Means with the same letters are not significantly different at P < 0.05.

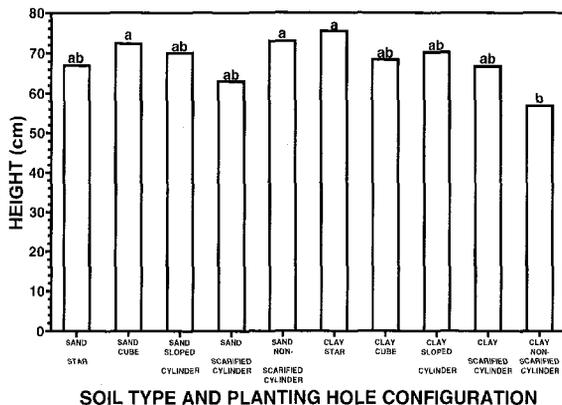**SOIL TYPE AND PLANTING HOLE CONFIGURATION**

Figure 4. Height (cm) of live oak seedlings at 125 days following transplanting to sand and clay soil monoliths with five planting hole configurations. Means with the same letters are not significantly different at P < 0.05.

cylindrical planting holes or clay soil with star-shaped planting holes.

At first glance the height data appears consistent with the premise that the glazed surfaces of non-scarified cylindrical planting holes in heavy clay soils could reduce overall seedling growth by impeding root growth into undisturbed soils outside the planting hole (Fig. 4). However such was not the case in this study as seedlings grown in cylindrical planting holes with non-scarified surfaces in clay soil had the greatest root dry weight outside of the original planting hole (Fig. 2). Furthermore, scarified cylindrical planting holes had the least root growth into the surrounding soil of all planting hole types in clay soils (Fig. 2). Very few instances of root deflection at the backfill - native soil interface were observed for any of the planting hole configurations regardless of soil type. The variety of potential angles of deflection created with the various planting hole configurations and the lack of root deflection suggests that at least with live oak the angle at which a root contacts the planting hole surface is not a significant factor in soil penetration as was suggested by Nicolosi (5). Watson et al. (10) also reported no restriction of root growth of container-grown *Cotoneaster apiculata* or *Juniperus chinensis* across the interface between backfill soils and surrounding clay soils, even when backfill soils were amended with lower bulk density organic matter. Root dry weight

inside the rootball and in backfill outside the rootball did not differ significantly ($P < 0.05$) among planting hole configurations (data not presented), suggesting that roots were also not impeded at the container medium - backfill interface.

Beeson (2) reported that reductions in stomatal conductance of live oak did not occur until water potentials of stems were more negative than -1.8 MPa. Maximal water stress in the present study, as indicated by mid-day water potential (Fig. 5), exceeded this stomatal conductance limiting level only during the first 21 days following transplanting. Beeson (2) reported that 15 to 20 weeks were required for transplanted 10 cm caliper live oaks to reach pre-dawn water potential of about -0.1 MPa indicating a recovery of transpirational losses from the previous day. Similar pre-dawn water potentials were observed at 125 days after transplanting in this study (Fig. 5). There were no significant effects ($P < 0.05$) of planting hole configuration on mid-day or pre-dawn water potentials.

Field test. Height and caliper growth in the field were greater during the second year following transplanting (44 cm height and 9.1 mm diameter increases, nearly equal to growth during container production) than during the first year (10 cm height and 2.7 mm diameter increases) following transplanting suggesting that transplant establishment was complete after the first growing season. No significant effect of planting hole configuration on
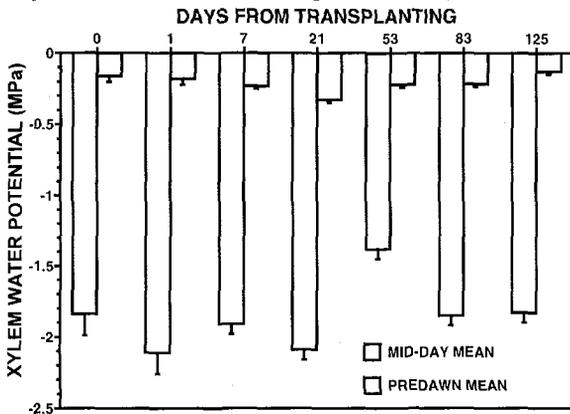
height was observed, but seedlings planted in sloped cylindrical planting holes had greater caliper after two years in the field than those in square or cylindrical planting holes (Fig. 3B). Overall growth of seedlings transplanted to sloped cylindrical planting holes was equal to or greater than that of seedlings in other planting hole configurations both in the field (Fig. 3B) and soil monoliths (Figs. 3A and 4). This did not appear to be related to an increase in root growth outside the planting hole (Fig. 2), and since the planting holes were all of equal height (15 cm) and volume (4860 cm^3), it might be attributable to the greater surface area of the top of the sloped cylindrical planting hole (Fig. 1). Assuming even distribution of irrigation or precipitation over the soil surface a greater quantity of water would be diverted directly into those planting holes with the greatest surface area at the top of the planting hole. Thus, sloped cylindrical planting holes might be beneficial on droughty sites. Under the moderate soil moisture conditions present in this study, planting hole configurations did not substantially affect shoot growth or plant survival.

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DAYS FROM TRANSPLANTING

Figure 5. Mean (± standard errors) mid-day and pre-dawn xylem water potentials (MPa) of container-grown live oak seedlings transplanted to soil monoliths.

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Zusammenfassung. Von der *Quercus virginiana* wurden containergezogene Sämlinge in Pflanzbeete versetzt, die aus sandigem oder tonigem Boden bestanden. Weitere Sämlinge wurden an einen freien Standort im Felde in fünf Pflanzlochanordnungen gleichen Ausmaßes versetzt. Für die folgenden 125 Tage nach dem Verpflanzen wurde das Wachstum der Triebe und das Wasserpotential im Xylem gemessen. Die Wurzeln der Sämlinge wurden ausgegraben, um das Wurzelwachstum innerhalb des verfüllten Bodens und außerhalb des Pflanzlochs zu bestimmen. Die Sämlinge im Felde wurden für ein weiteres Jahr beobachtet. Keines der Pflanzlochanordnungen schnitt im Vergleich gut ab, aber die steilen, zylindrischen Gruben könnten an trockenen Standorten von Vorteil sein. Das Wurzelwachstum ausserhalb des Wurzelballens wurde durch das Medium nicht aufgehalten: weder durch den verfüllten Boden noch dessen Grenzfläche, weder durch die Pflanzgrubenwand unabhängig vom Bodentyp oder die Pflanzlochanordnung. Die Gestaltung des Pflanzlochs hatte keinen Einfluß auf das Wasserpotential im Xylem.