greater agreement than the landscape professionals group, perhaps because they were more homogenous. The landscape professionals had different opinions because they represented a variety of segments of the industry—landscape installation, landscape maintenance, and garden center. Each had their own concerns. A more homogenous focus group might result in more consensus. The information provided by this group was varied but valuable. Focus groups are mechanisms for collecting qualitative information and cannot be used to estimate the size of a market or to make broad assumptions about the entire market. They do supply factual and perceptual input into the managerial decision-making process (Paley, 1995).

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Establishing Pecan Transplants

Bruce W. Wood

Additional index words. containers, season, bare-root, size, pruning, cultivars, roots

Summary. Pecan [*Carya illinoinensis* (Wangenh.) K. Koch] nursery transplants performed best on establishment in nonirrigated orchards when using large trees planted early in the dormant season. After 6 years, growth and survival of bare-root transplants were equal to that of containerized transplants when established during the dormant season. Reducing transplant trunk height by ≤75% at planting did not affect subsequent tree survival, although rate of height growth and tree vigor increased such that there was no difference between pruned and nonpruned trees after 3 years, except that pruned trees appeared to possess greater vigor. There also were no differences in growth or survival between augured and subsoil + augured planting sites within 6 years of transplanting, and there were no differences between root pruned (severe tap or lateral root pruning) and nonpruned trees.

Nursery-produced pecan trees often are transplanted in yards or in small orchards in which supplemental watering is highly irregular or lacking. Under such conditions, transplant survival and subsequent growth can be poor. The increasing popularity of pecan in such plantings merits greater understanding of how transplanting practices influence survival and tree growth. Factors such as root pruning (Overcash and Kilby, 1978; Romberg and Smith, 1939; Woodroof and Woodroof, 1934), shoot pruning (Smith and Johnson , 1981), containerization (Laiche et al., 1983), tree size (Roper, 1927; Stuckey and Kyle, 1925), and soil compaction (Wood and White, 1986) can influence growth and performance of pecan transplants, although these fundamental aspects of pecan establishment have received little objective study. My purposes was to assess 1) use of bare-root vs. containerized transplants, 2) small trees vs. large trees, 3) tap root or lateral root pruning vs. no root pruning, 4) time of year to transplant, 5) amount of the tree trunk to remove at time of planting, and 6) influence of subsoiling the planting site before planting on transplant performance.

USDA, Agricultural Research Service, Southeastern Fruit and Tree Nut Research Laboratory, Byron, GA 31008.

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Materials and methods

Transplanting strategies were evaluated in a series of four studies on sites [Faceville fine sandy loam (2% to 5% slope) soil] prepared by disking to 15 cm and liming to 809 $kg \cdot ha^{-1}$. Subsequently, in March, trees received an annual treatment of 454 g of 10–10–10 (10N–4.4P–8.3K) per 2.54 cm of trunk diameter until age four, and then they received dolomitic lime at 809 $kg \cdot ha^{-1}$ and N, P, and K, at 247 units / ha broadcasted in March (also based on 2.54 cm of trunk diameter). Transplants were compound trees (generally 3:1 types, or 3-year-old roots and a 1-year-old scion) planted in augured 0.46 × 0.91-m holes. Data were analyzed using SAS's analysis of variance, GLM (SAS Institute, Cary, N.C.). The amount of rainfall the plantings received the year of transplanting is depicted in Fig. 1. Transplants were established within 1 week of digging.

Amount of stem removal. The response of transplants to different degrees of trunk removal was assessed using compound trees of 'Desirable' scions on 'Elliott' seedling rootstocks. Trees were between 2.4 and 3 m in height, excluding roots, and were planted Feb. 1989. The experimental design was a randomized block (15 blocks) consisting of five pruning treatments per block (n = 75) where 0%, 10%, 25%, 50%, or 75% of the original trunk length was removed. Transplants were irrigated with ≈20 L of water at time of planting to pack soil around the roots but were not watered after the initial watering, except by natural rainfall (Fig. 1). Dependent variables were tree height, trunk diameter at 30 cm, and total length of the five longest limbs. Data were evaluated for linear, quadratic, and cubic effects.

Root pruning, tree size, and site preparation. The experiment was structured as a randomized block (12 blocks) with a factorial arrangement of three treatment classes (n = 288). Treatments were root pruning (no pruning, lateral roots shortened to 10-cm stubs, half of the tap root removed, and a combination of the latter two), tree size [tree height classes (in meters) of 2.4 to 3, 1.8 to 2.4, and 1.2 to 1.8)], and site preparation (standard 0.46 × 0.91-m, cylindrical, augured holes with ripping to 61 cm for 1.8 m radiating in each cardinal direction from the hole or planted without ripping). Bare-root 'Pawnee' (on Elliott rootstock) transplants were established in Mar. 1988. Trees were trained to central leaders. Crown diameter and tree height were measured after 5 years.

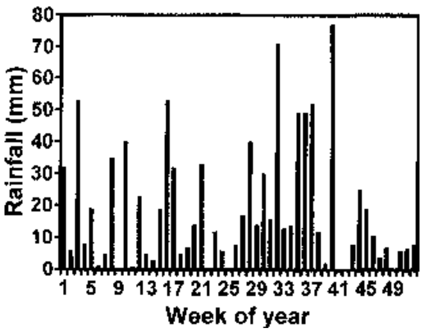

Fig. 1. *Amounts of rainfall received at transplanting site during the first year that trees were planted. Depending on the particular experiment, transplants were generally established between January and April.*

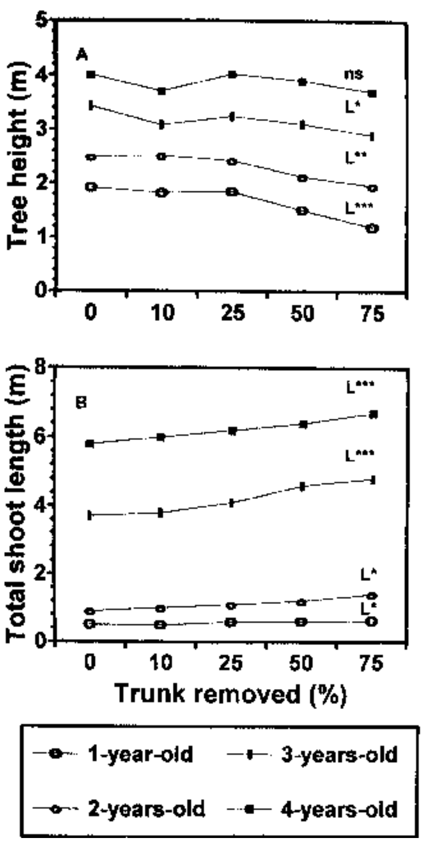

Fig. 2. *Influence of cutting back different percentages of trunk on A) height and B) shoot growth of bare-rooted 'Desirable'/Elliott seedlings (3:1) nursery transplants. There were significant (α < 0.05) linear (L) responses in 3 of the 4 years in which measurements were made.*

Month of transplanting. Time of year of transplanting was evaluated using bare-rooted 'Desirable' (on Elliott rootstocks) transplants. Trees were planted in Winter and Spring 1988. Trees were dug within 1 week before transplanting and were established the first week of the month from December through April. The experiment was a randomized block with 12 blocks (n = 72 trees). Dependent variables were height, trunk diameter, and total length of limbs. Data were evaluated for linear, quadratic, and cubic effects as related to Julian planting date.

Comparison of containerized and bare-rooted trees. The relative performance of bare-rooted and containerized transplants was evaluated using 'Stuart' scions on 'Curtis' seedling stocks. Trees were planted Feb. 1988 in 0.46 × 0.91-m augured holes for bare-root trees or in a 0.46 × 0.46-m augured holes for potted trees. The potted trees were grown in a 30 × 30-cm cylindrical pot. Trees of both treatments were between 1.8 and 2.4 m in trunk height and were blocked according to stem diameter. The root ball of potted trees was sliced on each of four sides at transplanting to encourage root proliferation (Laiche et al., 1983). The root ball of potted trees also was covered with ≈9 cm of soil to retard drying of the artificial soil mix (Puls, 1989). Measurements were trunk diameter, tree height, and crown diameter. The experiment was a randomized block with two treatments (bare-rooted and containerized root mass) and 30 blocks (n = 60 trees).

Results

Amount of trunk removal. The amount of trunk removed from bare-rooted transplants influenced canopy growth (Fig. 2) but not survival (100% of all treatments lived, so data are not presented) or trunk diameter in subsequent years. Pruned trees eventually (after 4 years) caught up in height to nonpruned controls (Fig. 2A), whereas total shoot length of the five longest shoots exceeded the control throughout the test (Fig. 2B). These changes were linear and positively correlated to degree of pruning. By the end of the first three growing seasons, trees pruned by 75% were 62%, 79%, and 85% as tall as the nonpruned trees. Conversely, shoot growth of those having 75% of the trunk removed was 121%, 128%, and 123% (α < 0.05) greater than the nonpruned trees during the first 3 years after pruning. Pruned trees, therefore, grew at a greater rate of growth than nonpruned trees. These tree exhibited strong growth and appeared to exhibit greater vigor than nonpruned transplants.

Root pruning, tree size, and site preparation. Tree growth was affected by size of transplants (Fig. 3) but not by lateral or tap root pruning or subsoiling before planting. Furthermore; these treatments exhibited no interactions. By 6 years after treatment, height increased (based on pre-transplant trunk height) by 48% for tall, 79% for medium, and 138% for small trees, with the mean range between categories being 40 cm. Thus, the tallest trees maintained their height superiority for ≥6 years after planting. The same relationship held for canopy diameter. The height and diameter growth of root-pruned trees did not differ from nonpruned trees, although lateral roots proliferated at the base of the severed tap root.

Month of transplanting. Time of planting did not influence survival or trunk diameter, although tree height (Fig. 4A) and total shoot length (Fig. 4B) was linear and positively related to the earliness of transplanting. Growth of trees transplanted in late autumn or early winter was greater than those planted later in the winter or early spring. After the fourth growing season, tree height and shoot growth of December and January transplants were 122% and 135%, respectively, of those in early spring. Similarly, shoot growth of December and January transplants were 114% and 117% of late winter transplants, which is the typical time of transplanting in commercial orchards.

Comparison of containerized vs. bare-rooted trees. There were no detectable differences in survival, height, trunk diameter, or crown diameter between bare-root and container trees for at least the first 6 years after transplanting.

Discussion

As with most woody perennials, the survival and subsequent growth of pecan transplants can be improved by transplanting in early winter rather than early spring and by planting large-sized nursery trees. While these cultural practices reflect basic horticultural principles (Westwood, 1978), their application to pecan has not been quantified, especially for nonirrigated sites. Although growers increasingly are using larger transplants, there is little or no effort to capitalize on the 25% to 50% height or crown growth advantages these data indicate are associated with earlier winter transplanting. The assumption that small trees [0.9 to 1.5 m (3 to 5 feet)] survive better and are best for general planting (Roper, 1927) was not supported by the nonirrigated conditions of this study.

Recommendations regarding the amount of the tree trunk to remove at transplanting vary, ranging from removing little to about half of the trunk (McEachern, 1993; Puls, 1989; Shoup et al., 1980; Smith and Johnson, 1981). My study indicates that removal of ≤75% of original trunk reduces tree height in the first 1 to 4 years, but size may not differ from that of nonpruned trees after 4 years. This greater rate of height growth exhibited by pruned trees during the first few years may possibly continue to exceed that of nonpruned trees after ≥6. While this was not determined, pruned trees appeared to exhibit greater vigor. These data were derived from bare-rooted trees having ≥90% of their original root system intact; therefore, transplants with higher levels of root loss may benefit to an even greater degree because of trunk pruning. The greater rate of height growth, as degree of trunk pruning increases, indicates that transplanted pecan trees likely would benefit from such practices.

The height growth of pecan transplants under the nonirrigated conditions of this study was not affected by removing half of the tap or lateral roots. This indicates that pecan probably can tolerate substantial root loss before shoot height growth is affected. These data were observed on "compound" trees, managed with almost no supplemental watering the first year and differ from results observed by Smith and Johnson (1981) for "simple" trees ('Moore' seedlings) managed with season-long supplemental irrigation.

Equivalent growth responses of healthy and vigorous containerized vs. same-size, bare-root, 'Stuart' (on 'Curtis' seedling rootstock) trees indicate that selection criteria be based on factors other than growth or survival when the tree is to be planted in the dormant season. These data for 'Stuart' (on 'Curtis' seedling rootstock) confirms those reported for 'Cherokee' (on an unknown seedling rootstock) by Laiche et al. (1983), in which, after 5 years, there were no differences in tree height or trunk diameter because of the trees being either a bare-rooted or containerized transplant. This indicates that the relationship between the two transplant types is likely to be general for most scion–rootstock combinations. The containerized tree likely may exhibit substantial advantage over bare-rooted transplants if a post-budbreak planting date is necessary.

Pruning lateral roots before backfilling with soil to stimulate root proliferation or to avoid a potential retardation in growth because of the packing of lateral roots against the tap root on backfilling with soil did not influence tree growth. Similarly, attempts to increase tree height by inducing lateral root proliferation by removing half of the tap root, as suggested by others (Overcash and Kilby, 1978; Romberg and Smith, 1939; Woodroof and Woodroof, 1934), were unsuccessful in my study.

Hardpans in soils can influence pecan tree performance by inhibiting root penetration (Wood and White, 1986). In this study, efforts to facilitate root penetration on a plow-pan site had no effect on subsequent tree growth, indicating that a hardpan must be severe if it is going to influence transplant growth during the early years after orchard establishment.

My research indicates that, for nonirrigated environments typical of many small orchard and yard type plantings in the southeastern United States, survival and height growth of transplants may be maximized by planting large trees, either bare-root or containerized, in December or early January and then substantially pruning the trunk to enhance the rate of height growth, tree vigor, and survival. Tap and lateral root pruning of bare-rooted transplants immediately before plant-

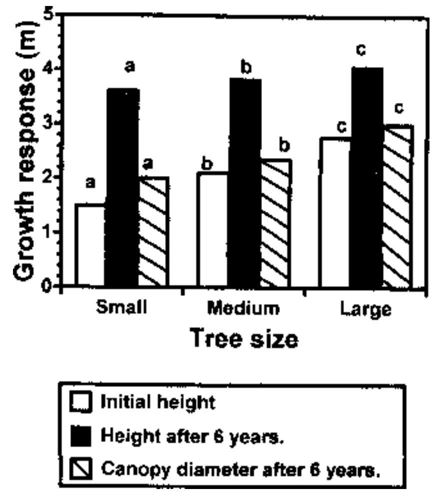

Fig. 3. *Influence of size of bare-rooted 'Pawnee'/Elliott seedling (3:1) nursery transplants on A) height and B) canopy growth after 6 years. Means with different letters within each dependent variable are significantly different at $\alpha < 0.05$.*

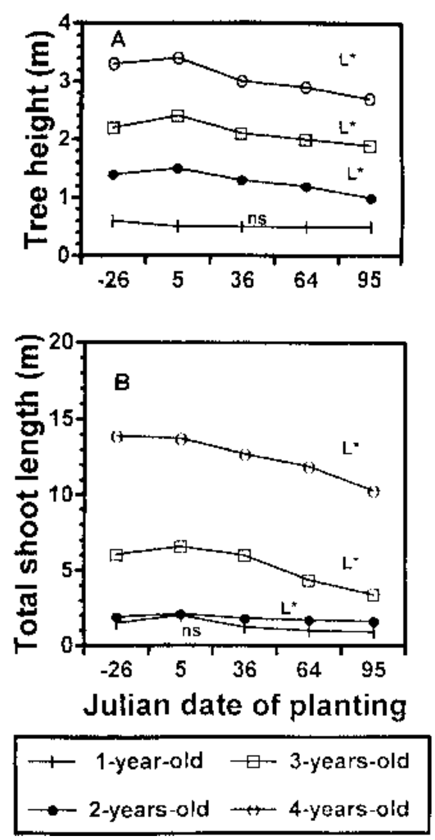

Fig. 4. *Influence of month of transplanting on subsequent A) height and B) shoot growth of 'Desirable'/Elliott seedling (3:1) bare-rooted nursery transplants. There were significant ($\alpha < 0.05$) linear (L) responses in three of the four years in which measurements were made.*

ing does not appear to influence the subsequent rate of height growth. Additionally, containerized transplants appear to offer no growth advantage over bare-rooted trees when established in the dormant season.

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