# TREE PLANTING FUNDAMENTALS

**by J. Roger Harris and Nina L. Bassuk**

**Abstract.** Transplanting imposes severe physiological stress because over 95% of the root system is removed when the tree is dug. The landscape designer and contractor can make decisions that will improve the chances of success. Advantages and disadvantages of purchasing trees produced by different production methods are discussed from the landscape contractor's point of view. Current research concerning key steps in the planting process is reviewed, and recommendations are made.

Tree selection, planting and establishment is a many-faceted process in which tradition plays a fundamental role. Contemporary research has questioned many of our traditions concerning the transplanting operation such as the morphology of root systems (36), the addition of soil amendments to the backfill soil (49), the pruning of up to 1/3 of the canopy at transplanting (39) and the wrapping of trunks (32). Trees are complex organisms, and transplanting success depends upon interactions among the physiological condition of the tree at the time of transplanting, climate, micro-climate, soil conditions and post-transplant care. Research reports often contain conflicting results because these intricate interactions are seldom consistent among investigations. However, controlled conditions usually necessitate the use of small trees in laboratory conditions, and such results are often not very applicable to landscape-sized trees in an open environment.

## The Problem

Trees have a remarkable capability to survive catastrophic stresses such as transplanting. A tree growing in a reasonably undisturbed mesic site rarely has a tap root, has a horizontal root spread that is 2.5 - 3.0 times greater than the crown spread, has most (>60%) roots outside of the drip line, has most (>95%) roots in the top three feet (1 m) of soil, and has most fine, or smallest diameter, roots in the top 6 in (15 cm) of soil (15,16,36,47). It is obvious from this generic description, that only a small percentage of these roots will be moved when the tree is transplanted. Estimates of the roots left at the nursery are from 91 - 98 % (15,47). Cultural practices in the nursery such as root pruning (21), irrigation (23), fertilization (8), root-ball configuration (42) or production method (19) can influence the percentage of harvested roots. Water stress, caused by the removal of most of the water absorbing organs of the plant, is the major cause of transplant failure (27). Removal of root tips also reduces the number of sites of hormone synthesis and a disruption in root signal to the shoot occurs. Such a disruption can cause a reduction in post-transplant photosynthesis (18). Once transplanted, irrigation management is critical because not only the root system, but the available reservoir of water has been reduced. Most of the water absorption capability within a transplanted root-ball is a result of small diameter roots (18). These fragile roots are the first to suffer from desiccation. Traditional wisdom states that trees with coarse roots do not transplant with as much success as trees with a root-ball containing smaller, more branched roots. Research has for the most part borne this out (11). Root-balls with fewer, but larger roots may have equal root dry weight as root-balls with smaller diameter roots, but the absorbing power is less because smaller roots have a larger root surface per unit of dry weight. The ability to survive the removal of much of the root system is indicative of a plant's ability to endure with sufficient vigor long enough to allow for the regeneration of roots into the surrounding backfill. Factors that contribute to the root regeneration potential of the transplant include the amount of carbohydrates stored for root regeneration energy (46), the ability to tolerate or avoid desiccation (25) and a physiological ability to function while roots regenerate (3).

## Sources of Plant Material

Modern landscaper contractors and landscape architects must choose species, size, and production method. Traditionally, the choice was between bare-root or balled and burlapped (B&B) trees. The advent of container growing after WWII, the recent introduction of the fabric container, and improved shipping methods have, however, complicated the picture. Landscape-sized trees are now produced in containers throughout the sun belt and many growers are experimenting with fabric containers. Improved shipping ability, aggressive marketing and over wintering facilities have made trees produced in warmer climates available for planting in other parts of the country.

**Above-ground containers.**

*Advantages.* The primary advantage of using trees produced in containers is that 100% of the root system is moved with the transplant. The plant therefore undergoes no transplant shock if given adequate post-transplant care. This is a real advantage if the tree is to be planted during the growing season, when removal of part of the root system predisposes the rapidly transpiring tree to shock. The season of planting is therefore much extended.

Container-grown trees are generally much lighter than B&B trees because the perched water table created by the container requires the use of a well drained, and therefore lighter, potting mix. This facilitates easy handling and shipping. A 2 in (5 cm) caliper tree produced in a container can be lifted by two people, but a 2 in caliper tree B&B would require a tractor. Container-grown trees can be loaded and unloaded much more quickly than B&B trees.

*Disadvantages.* Perhaps the principal disadvantage of container-grown trees is the possibility of deformed root systems. Roots do not continue encircling the root-ball when planted but will grow straight into the backfill soil if reasonable tilth is present (14). Problems arise, however, when the trees have been held for too long a time in the container. This 'pot-bound' condition reduces the vigor of the plant in the nursery and has a dwarfing effect on the tree. Dwarfed container trees are no bargain. The entangled mass of roots is a physical barrier to root regeneration, and the tree may develop girdling roots.

Container-grown trees are often more expensive than B&B trees because of increased production costs. Container production requires that most capital expenses be invested before harvest, whereas B&B production requires much of the expense at harvest after the plant is already sold. For this reason, larger sizes are often unavailable in container-grown trees. Since roots are less cold hardy than shoots, container-grown trees may need winter protection in the north, further increasing their cost.

Irrigation is required more frequently when planting container-grown trees. When a container of porous media is planted into a finer textured soil, thereby removing the perched water table, water drains from the potting mix into the surrounding soil. A container-grown tree may therefore need more irrigation after planting than it did before (34). Container-grown trees also have high post-transplant transpiration rates. Since 100% of the root system is planted, the tree transpires at pre-transplant levels, using up the available water quickly. In other types of transplants, stomatal response to root severance conserves moisture by reducing transpiration thereby depleting the available soil water reservoir less quickly.

**Fabric containers.** The use of fabrics to control root growth was introduced by van der Werken (44) and refined by Reiger and Whitcomb (38). The fabric container is placed in the ground, backfilled with native soil, and the tree liner is planted in the container. The fabric container is removed at transplanting. Roots can penetrate the container, but radial expansion is limited, thereby producing a girdling effect. The girdling effect, in theory, causes a concomitant increase in root branching inside of the container and a general increase in the fibrous nature of the transplanted root-ball.

*Advantages.* Speculated advantages of fabric container-grown trees are 1) faster and easier digging, 2) a higher proportion of roots are contained in the root-ball, 3) digging and planting season are extended beyond that of traditional B&B, and 4) root-balls are smaller and lighter than B&B (50). Research to date has shown that the fabric container does produce a more compact root system on many species. However, a corresponding increase in post-transplant root regeneration does not always occur (6,13,19).

*Disadvantages.* One disadvantage of using trees produced in fabric containers is their relative newness on the market. Growers and landscape contractors alike have little experience handling trees produced by this method, and few research data are available.

Plant response to the fabric container appears to be species specific. Harris and Gilman (19) found root-balls of laurel oak to be unaffected by production in fabric containers, but slash pine and Leyland cypress were. In another study (18) which examined the post-transplant response of East Palatka holly, trees produced in fabric containers had a root-ball with more small diameter roots compared to B&B trees. Root surface area was about the same in fabric container trees and B&B trees, even though the fabric container-grown root-balls had one-half the volume of B&B grown trees. Fabric container-grown trees were more stressed immediately after transplanting and in a subsequent drought experiment. This was due in part to a disruption of the root-ball upon removal of the fabric (13). This response may have been a result of the sandy, north Florida soils and may not occur in finer textured soils. Since fabric container-grown trees had smaller volume root-balls than B&B, their water reservoir was depleted faster. Recovery, however, was rapid. At the end of the drought experiment, all trees of both production systems were irrigated daily for two weeks, and there was no difference in dry weight of regenerated roots between production methods. Fabric container-grown trees may need staking after transplanting due to the smaller root-ball.

**Balled and burlapped.**

*Advantages*. Moving B&B trees is the traditional method of transplanting. Workers are used to handling B&B trees, and consumers are used to seeing them planted. In addition, B&B trees are readily available. Large sizes are available, and are limited only by the equipment available to lift and ship. A major advantage to planting B&B trees as opposed to trees produced by other production methods is that soil types can be matched, thereby reducing any interface problems that might inhibit water flow between the surrounding soil and the root-ball.

*Disadvantages.* The main disadvantage of field-grown trees moved B&B is that over 95% of the roots are left behind when dug (15,47). This may be overcome somewhat by cultural methods such as root pruning (48) or by buying relatively small trees which were lined out from containers. Harris and Gilman (18) harvested 51% of total root length of East Palatka holly transplanted B&B 17 months after lining out from 1 gallon containers in Florida. Trees moved B&B are subject to seasonal restraints, although many operators use special care and move trees year round. The most favorable seasons are when transpiration demand is low and root regeneration potential is high. These do not usually coincide, since the most favorable time for root regeneration is probably after the first flush of growth has hardened (31). With the much reduced root system, water relations following transplanting are most important (27). B&B trees are heavy. Moving landscape-sized B&B trees requires equipment and skilled personnel to operate it.

**Bare-root.**

*Advantages.* Advantages to planting trees bare-root are primarily financial. Bare-root trees are much cheaper than trees produced by other production methods because of ease of digging, storing and shipping. Many species respond well to moving bare-root. Longer root lengths are possible since weight is of little concern. Bare-root trees can potentially retain a greater proportion of the original root system. Inspection of the entire root system is possible, and inferior root systems or defects, such as girdling roots, can be detected.

*Disadvantages.* The range of sizes obtainable from other production methods are not available for bare-root transplants, since larger sizes usually do not transplant very well. Many species of trees cannot be moved bare-root (20). This is primarily due to a lack of desiccation tolerance (5). Careful attention to handling is required because the exposed root system must be protected from drying influences.

Transplanting bare-root trees is more affected by seasonal restraints than other production methods. Trees should be dormant. Short windows of opportunity in northern latitudes can be a major restraint when summer comes ‘quickly’ or winter comes ‘early’. Larger bare-root trees usually have to be staked since a leafy crown without a secure root-ball is more subject to windthrow in the spring.

## Size

Smaller trees generally transplant better than larger trees. There are, however, reported exceptions. Staley and Dickson (41) found that larger sizes of willow and pin oaks transplanted better than smaller sizes, and Larson (29,30) reported that larger-sized seedlings of red oak transplanted better than smaller seedlings. For landscape-sized trees, however, such reports are the exception to the norm. Large diameter trees are often specified for instant effect, but post-transplant physiological stresses, as well as effort expended (and associated costs), increase exponentially with tree size.

The growth rate of regenerated roots is mostly unaffected by tree size (46). Trees characteristically maintain a root:shoot ratio (28), so transplanted trees do not put on significant shoot growth until the pre-transplant ratio has been reestablished. Watson (45) used a growth rate for roots of 18 in (45 cm) per year to calculate that a 4 in (10 cm) diameter tree and a 10 in (25 cm) diameter tree planted at the same time will be of equal size 13 years after transplanting. This is because the total amount of the root system needed for replacement is much more for the 10 in tree, even though similar percentage of roots are removed. The 4 in tree will have reestablished the original root system at the end of 5 years, and will start to increase in size thereafter. The 10 in tree, however, will take 13 years to replace the roots lost at transplanting. Whitcomb (52) noted that the area of living cells on either side of the cambial layer of a 5 in tree was 40 times more than that of a 1 in tree, further demonstrating the stress magnification involved when transplanting large trees.

## Planting Procedures

The landscape contractor can control the planting process. Careful attention will pay dividends in a healthier tree and a satisfied customer. Good technique begins with the unloading of the tree. Trees should never be lifted by the trunk. Trees are particularly vulnerable to damage if active growth has begun. Cambial cell walls are thin when growth resumes in the spring, and the bark (phloem and tissues outside of phloem) is easily 'slipped' (9). Trees that are moved B&B are particularly susceptible because of the weight of the root-ball.

**The planting hole.** The addition of soil amendments to the backfill is a time honored tradition, and use is still recommended by some contemporary horticulturists (12,26). Most research, however, reveals that the amendments offer no consistent advantage (7,24,) or even may prove harmful (4,35,49). Backfill should, in most cases, be the soil removed from the planting hole. If the backfill is of extremely poor quality, good topsoil is the best alternative (51), or better yet, don't plant a tree in that spot. An exception is the case where entire beds can be amended, such as to leave room for several years root growth. The most important contribution to the backfill is increased aeration (2). This is best accomplished by digging a hole that is no deeper than the root-ball and at least three times as wide (7). Digging a deeper hole creates an opportunity for settling of the root-ball and an increased chance of root suffocation. Backfill should be lightly tamped periodically as it is returned to the planting hole to eliminate air pockets. Air pockets create a problem with water movement and will decrease the volume of soil available for root regeneration.

**Root-ball coverings.** Coverings to retain intact root-balls are necessary and increase in number and type with the size of the root-ball. Burlap should be pulled down from the top of the ball at planting, and twine should be removed from around the trunk. Burlap exposed at the surface can act as a wick to dry out the root zone. Synthetic burlap does not degenerate in the soil and will girdle roots. Large root-balls are often covered with wire fencing or specially designed baskets which hold the balls together during transit. The effect of wire baskets on future health of trees is a subject of concern and debate. Recent research in Canada (17,33) alleviates some concerns for trees already in place, but the question of removal before planting has not been answered with certainty. Tree response to root girdling by wire baskets is likely species dependent, and further information is needed. Until the question has been answered more definitively, it is best to remove wire baskets before planting or to place the tree in the planting hole with the wire intact and remove or fold down the upper half of the basket. This will allow the majority of roots to escape girdling.

**Wrapping, staking and guying.** Trunk wrapping is another tradition whose effectiveness has recently been questioned. Trunk wraps, in theory, help prevent sun scald and frost cracks, particularly on trees with thin bark such as birch and maple. They also help deter damage from rodents and offer some protection from mechanical damage. Litzow and Pellet (32) tested the effectiveness of paper trunk wrap in buffering trunk temperatures and reported that temperature fluctuations were actually greater under wrapped trees than where no wrap was used. The most effective material was a greenhouse insulation material. The effectiveness of other materials are currently being studied by researchers in Virginia (1). A survey of ISA members reports that many wrap trees primarily to give physical protection from vandals and equipment.

Staking and guying newly transplanted trees is often unnecessary. Prolonged staking and guying not only reduces normal taper of the trunk (20) but is liabile to cause accidents, particularly if guy wires are not clearly marked. Guys that are not removed after one growing season can quickly disfigure and girdle the tree. There are situations when staking is advisable, however. Trees that were staked in the production nursery will often require continued staking in the landscape. Trees in very open and windy sites, particularly in wet conditions, will also require staking. The decision to wrap, guy and stake should be made on an individual tree-by-tree basis and should not be required for all plantings.

**Pruning.** A standard recommendation to landscape contractors has been to prune back 15-40% of the top prior to transplanting (10,26,27). The premise is that pruning the top will reduce the amount of new growth during the spring flush, and that transpiration demands and the resulting water deficits will be reduced. Shoup et al. (39) reported that degree of pruning had no effect on survival, but that pruning more than 15% of the tops before transplanting reduced the visual quality of all species. Ranney et al. (37) reported a decrease in transpiration on cherry trees pruned 50% before planting, but a reduction in growth rate of roots as well as shoots occurred compared to unpruned controls. The benefits of indiscriminate dormant pruning of deciduous trees at planting are doubtful. Pruning should be restricted to corrective pruning to improve form only.

**Fertilization.** Recommendations for post-transplant fertilization vary considerably. Some researchers report no effect of fertilization at plantings (39,40,43) while others report significant response (22). No advantage has been demonstrated to any form of application except broadcasting evenly upon the soil surface, but a slow release type fertilizer may be mixed with the backfill if desired.

## Summary

Transplanting stresses trees because 95% of the root system is removed when the tree is dug. Some production methods remove fewer roots, but no method is best for all situations. Production method should be chosen according to availability, price and adaptability to local site conditions. Plants should be handled by the root-ball and planted in a hole that is no deeper than the height of the root-ball. No amendments should be added to the backfill unless a large bed is prepared for several plants. All burlap should be folded back from around the ball and not left exposed to air. Twine around stems should be removed. Synthetic burlap and wire baskets should be folded back or removed. Deciduous trees that are transplanted while dormant should be pruned only for corrective reasons. The decision to wrap trunks and stake trees should be made on a tree-by-tree basis.

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**Résumé.** Les avantages et désavantages lors de l'achat d'arbres produits selon diverses méthodes sont discutés selon le point de vue des contracteurs. Ces divers types de production incluent la production en contenants enterrés dans le sol, en contenants de plastique, en motte emballé de jute et à racines nues. La recherche courante sur les étapes-clés de la procédure de plantation est revue et des recommandations sont faites.

**Zusammenfassung.** Vor- und Nachteile des Baumkaufes unter Berücksichtigung verschiedener Baumschulmethoden werden aus der Sicht des Auftragnehmers besprochen. Dies schließt Pflanzen mit überirdischen Containern, Stoffehältern sowie Pflanzen mit und ohne Ballen ein. Die gegenwärtige Forschung befaßt sich mit allen wichtigen Schritten der Pflanzung und gibt Empfehlungen hierzu.