"What the World Needs Now:" Increasing Urban Tree Survival

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For: GLTE

Transplant shock refers to a period of reduced growth following transplanting. The practices outlined below will significantly affect the growth of the tree especially in the first year. The trees may have reduced regrowth potential that will be expressed as shoot dieback, transplant shock, or death. Transplant shock can last up to three years, and appreciably affects a manager's bottom line.

Check and Fix before Planting:

Compaction. Soil structure is fragile and can be damaged or destroyed by equipment, traffic, and excavation especially when done on wet soils. Loss of organic matter also weakens structure. Compaction alters the structure of the soil, squeezing macropores into micropores and creating horizontal aggregates that resist root penetration and water flow. Compaction reduces infiltration and aeration, increases the risk of runoff, restricts root growth, and makes it difficult for plants to become established. Compaction can be a problem in soils of any texture. Excessive tillage reduces the size of soil clods. This can contribute to compaction, crusting and increased erosion. It is best to break up compacted soils or hard pans before you plant use a shovel plough for sub-soiling to a depth of 2 feet, every 3.5 to 4 ft. in a cross lattice type pattern across the field. Spading machines are also used to break up compacted soils and have the advantage over sub-soiling in that they do not bring up sub-soil to the surface; however, they are expensive to run and will not break up hard pans.

Drainage. Slopes of 1 to 2% are easy to manage and provide good surface water and air drainage. Slopes greater than 5% will be susceptible to erosion. To check if additional drainage may be required dig a hole, 30 cm wide by 30 cm deep. Fill the hole with water to drain away. Once the water has drained away, fill the hole again with water. If water remains in the hole after 24 hours, the site may require additional surface grading or subsurface drainage. Water infiltration rates for various soil types are noted in Table 1. Table 1 illustrates the need for drainage increases with finer textured soils. Growers need to take extra precautions if their sites have heavy soils or are naturally poorly drained. The site needs to be sloped to achieve flow in the drain lines approximately 2%.

Table 1. **Water infiltration rates of various soil types, expressed in inches per hour.**

Soil Type	Infiltration rates (inches/hours)
Sand	> 0.8
Sandy & silty soils	0.4 to 0.8
Loams	0.2 to 0.4
Clay soil	0.04 to 0.2

Source: Horticulture Information Leaflet 551, North Carolina State University

Sod Covers and Green Manure Crops

Sod Covers and green manure crops improve soil structure, adds organic matter and can reduce soil erosion by 90%. Grasses combined with legumes grown for two years for maximum benefit. The dense root system produces a large amount of organic matter. Tap-rooted legumes (e.g. alfalfa) improve soil drainage by loosening soil. Green manure crops grown for less than one season then plowed down, in late summer or fall, before setting seed. These crops are useful when a more effective two year crop rotation is not feasible.

Organic amendments are the best way to improve the plant environment in nearly all soils. Organic matter helps build and stabilize soil structure in fine-textured and compacted soils, improving soil permeability and aeration, and reducing the risk of runoff and erosion. When organic amendments decompose they form humus, which acts as a natural glue, binding and strengthening soil aggregates. Organic matter helps sandy soils hold water and nutrients. In addition, organic amendments provide food for soil organisms and increase biological activity throughout the soil food web.

The utility of organic soil amendments varies, depending on their carbon to nitrogen (C:N) ratio. Organic materials with a low C:N ratio, such as undiluted manure or biosolids, are rich in nitrogen. They are a good source of nutrients, but must be used sparingly to avoid over–fertilization. Materials with an intermediate C:N ratio (including many composts, leaf mulches, and cover crop residues) have lower nutrient availability. They are the best materials to replenish soil organic matter. Because they are relatively low in available nutrients, you can add them to the soil in large amounts.

Materials with a high C:N ratio (such as straw, bark, and sawdust) contain so little nitrogen that they *reduce* levels of available nitrogen when mixed into the soil. Soil microorganisms use available nitrogen when they break down these materials, leaving little nitrogen for plants. This process is called *immobilization* and results in nitrogen deficiency.

Yard debris is the major raw material in most local composts. Compost raw materials may also include animal manure, biosolids, food waste, or wood waste. Commercial compost is made on a large scale, with frequent aeration and/or turning to create conditions that kill weed seeds, plant pathogens, and human pathogens.

Any compost used as a soil amendment should be mature and have a C:N ratio in the range of about 15:1 to 20:1 to avoid problems of nitrogen immobilization and phytotoxicity. Compost should contain less than 1% inert matter (usually plastic) to avoid aesthetic problems. Acceptable salt content and particle size of composts will depend on the end use and the environment.

Typical recommendations for compost use as an amendment for ornamental plants range from 2 to 4 inches incorporated to an 8 to 12 inch depth of soil. The deeper the compost can be incorporated, the better. Particle size is typically ½ -inch minus, and the salt content of the compost-amended soil should not exceed 2.5 to 6 dS/m (salinity units), depending on the salt tolerance of the plants grown.

The Preplant Program

A spring planting is preferable to fall, as plants not established in their new locations before winter are subject to frost heaving and winter kill. "Deep ploughing," as it is described below is especially critical in regions where heavy clay soils are common. In these regions, between October and November, 12" furrows are cut across the field, creating the planting rows or "planting trench" for the stock the following spring. The furrows maybe cut again in January if soil and weather conditions allow. This practice of deep ploughing is conducted so that the frost breaks up the clay and stock is easily placed in the planting furrows in the spring. One of the main goals in nursery field production, be it liner or caliper tree production, is to produce a nice 360° root system. For this reason well-branched and fibrous rooted liners are the best choice for starting material and maintaining the 360° root ball in production at the caliper production nursery is important to overall plant health and stock quality. If the soil in the "planting trench", is not adequately broken up from the frost activity during the winter, than the roots of the liner may get pushed more into one direction. This one directional rooting most often appears as a "hockey stick" formation when the liner is dug up later in the season.

Another reason for the practice of deep planting is the timing of tree liner arrival from the west coast. If deep ploughing has not been completed when trees arrive in February and March, a March planting will be impossible. In March, the ground will still be frozen or the fields will be too wet to plough and plant. If planting is attempted, after the frost is out, the soils will still be extremely wet and the "hockey stick" roots will result. "Hockey stick" roots can be caused by improper planting procedures such as improper planting shoes on the planting equipment; however, they are most often the result or complicated by planting into soils that are "too" wet. In a field that has been deep ploughed correctly, an indicator of ideal planting moisture conditions is the tops of the dirt piles thrown up from the furrows appear white – "white caps."

Root Deformations and Planting

Root deformations, are a common problem of container-grown woody plants transplanted to the landscape and include circling roots, stem-girdling roots (Fig.1), kinked roots (Fig. 2), ascending and descending roots (Fig.1).

Fig. 1. Descending and circling root deformation on *Syringa reticulata* after being left too long in a 3-gallon container.

Fig. 2. Kinked root deformation after being left too long in a 3-gallon container

To improve container-plant growth and survival seven methods of root disruption when landscape transplanting, in increasing order of severity were described by Hummel et al. (2008):

1. Washed growing medium from root system
2. Combed, roots untangled and spread
3. Cut and spread with knife or shovel
4. Vertical cuts made through roots circling the root-ball periphery and the roots straightened **(most common)**
5. Washed roots near stem then cut and spread peripheral roots
6. Washed and pruned roots near stem then cut and spread peripheral roots;
7. Washed and pruned entire root system

Dr. Ed Gilman recommends a new method of shearing off the outside 1/2" of (substrate/root) material all around, after the container is removed and before transplanting as shown in Fig. 3 a and b.

Fig.3 (A and B) Roots are sheared off by removing ½” around entire circumference of the root ball before planting in the landscape or up-shifting to a larger container.

Dr. Gilman does not advocate vertical cuts around the root ball (as decribed in item four by Hummel et al. (2008) as these cause descending roots.

Fig. 4. Vertical cuts made through the root ball are thought to increase descending root.

The containers commonly used are smooth-walled, round containers inducing circling roots which may be more pronounced with smaller container sizes. Many problems also persist from the smaller container as shown in Figure 1. Increasing the duration of the plant in the container pronounces encircling roots and amplifies lack of root growth into the soil following planting in the landscape (Warren and Blazich, 1991). Container-grown plants may also have abnormal buttress root development (descending roots) beginning when seedlings are grown in deep cells with narrow diameters (Zahreddine et al., 2004). These alterations in root morphology may be more pronounced with smaller container sizes and could predispose plants to drought stress in out-planting (NeSmith and Duval, 1998).

Too Deep

Planting too deep is also thought to result in root circling (Johnson and Hauer, 2000). The depth from soil surface to the root systems affects root circling because roots respond to oxygen limitations by growing into oxygen-sufficient areas, typically near to the soil surface (Mathers et al., 2007) (Fig. 5). The ascent of roots to the surface often causes roots to lose their normal outward radiating pattern and/or cause kinked roots (Johnson and Hauer, 2000). Roots that radiate toward the stem can later become stem girdling roots (SGR). SGR's enlarge over time and, in combination with the normal enlargement of the buried stem, creates a compressed, weak point in the tree's stem (Harris et al., 2004). There is a general decline in the remaining root system and movement of water and nutrients is impeded due to stem compression (Johnson and Hauer, 2000). Trees with SGR's may suffer slow decline, severe dieback and cambial death following cold winters or periodic drought, die prematurely or fail suddenly in wind and ice storms.

Fig. 5. Root ascend to the surface due to planting too deep.

Not Deep Enough

However, growers have long argued some nursery stock is being planted with exposed root tissue or a “root shank”. Gilman describes the "root shank" as an area of exposed (original) root tissue that results from tree seedling production practices.

Fig. 6. The root shank is that tissue (bright orange) that is root tissue but will be planted above the ground or the adventious root flare.

Plants produced in seed beds and then mechanically harvested are severely root pruned (main root cut off 10 cm below ground level) and laterals are stubbed. Seedlings are then mechanically planted at field spacing to develop into whips and branched trees. The "root shank" forms because roots regenerate from the cut end (what will become the "adventitious root flare") and the normal lateral roots above the cut typically just atrophy thus forming the "root shank". So the "root shank" was root tissue (originally) but now appears as stem tissue. The fate of this "root shank" as it relates to environmental challenges like cold hardiness, herbicides, and sunburn or sunscald have not been investigated. But it may be one reason for an increased incidence of crown injury.

Fig. 7. The crown is the last area to harden off in the fall. If root tissue is planted above ground it will increase susceptibility to this kind of injury.

According to (Chandler, 1954; Pellett, 1971; Pellett and White, 1969; Weiser, 1970) the root system of a plant is considerably less cold hardy than its stem tissue under field conditions. Therefore, if a plant's roots are exposed to ambient conditions due to high planting it may not overwinter properly and may die. Stem tissue and root tissue have very different anatomical features; the greatest difference is that the vascular system of stem tissue towards the outside, while that of root tissue is in the center.

Pot bound roots are defined as having roots so densely matted as to allow little or no space for further growth (Merriam-Webster Dictionary, 2010). During active growth, if a pot bound plant is not out-planted or upshifted, the growth of the plant will be severely stunted. This study compares the effects of looks at the various options for managing pot bound trees and includes three objectives: 1) determine the influence of planting depth on overall growth; 2) determine the influence of planting depth on overall hardiness of the plant; and, 3) determine the influence the four treatments of root manipulation at upshift has on pot bound plants.

Materials and Methods

Planting Depth

In the Spring of 2008, two species of oaks, *Quercus acutissima* and *Quercus rubra,* were sown, half at the soil surface and half planted too deep. In spring 2009 these seedlings were transplanted into three gallon containers. Four treatments were imposed: seeds sown at surface were planted correctly (at crown level); seeds sown at surface were planted high; seeds sown too deep were planted deep; and, seed sown deep were planted too high. Plants were grown for the summer of 2009 and overwintered in a flat roof cravo in the 3 gallon pots at Ohio State University, Columbus, OH.

On April 21, 2010, plants were transplanted in the field at The Ohio State University's Waterman Farm (Columbus, OH). The following four days included 4.47 cm of rain, so no irrigation was immediately applied. Irrigation was applied throughout the summer on an as needed basis based on rainfall observations. The plants were planted in a completely randomized designed with 1.54 meters within the row and 3.05

meters between rows. Plants were transplanted in the field at the same depth they were transplanted in the 3 gallon container. Grass was seeded between the rows at a rate of 60 lbs./acre between rows on April 22, 2010 with a blend of creeping red fescue 48.73%, perennial rye grass 14.74%, chewings fescue 19.8%, and Kentucky bluegrass 14.55%. Scotts 33-3-6 Field Fertilizer ER was applied on April 22, 2010 at 200 lb./ac around the trees in a 0.914 meter x 0.914 meter area. Trees were staked in the field. A soil analysis was performed on April 28, 2010: pH 7.2, LTI 70, P 66 ug/g, K 352 ug/g, Ca 3,227 ug/g, Mg 606 ug/g, and a CEC 22.1. Weed control included spot applications of 5% glyphosate on May 5 and June 7, 2010. Tillage was performed on July 6, August 6, and September 30 with a 5 HP front-tine tiller. Mowing was performed as needed throughout the growing season.

Root Disturbance

Syringa reticulata and *Tilia cordata* tissue culture plugs which had been left in one gallon pots for two years and were completely pot bound, were up-shifted on June 18, 2008 into 7 or 15 gallon pots. Plant height and caliper were obtained on June 18 and June 20, 2008, respectively. Potting media was a blend of pine bark, aggregate, and Comtil. Comtil is a composted municipal sewage sludge product that acts as a controlled release N fertilizer (Falahi-Ardakani et al., 1987), but is responsible for a small (<1%) proportion of the total nitrogen taken up by the crop (Struve, 2002). There were four treatments imposed on the two genera: undisturbed; four cuts through the root ball at N,S,E,W; removal of ½ inch of the root ball around the pot (Fig.3); and washing off the media from the roots.

Plants were fertilized with a Scotts, controlled release 19-5-8 formulation. Overhead irrigation was supplied in a flat roof Cravo system at OSU, Columbus. Plants were staked with 8 ft. bamboo stakes, evaluated at initiation, and arranged in a completely randomized design. Plants were harvested after final caliper and height measures were taken on November 7, 2008. Roots were taken from the trunks, dried in adrying oven, and then weighted.

Data Analysis:

All data were subjected to analysis of variance (ANOVA) using the general linear models (GLM) procedure within SAS® (SAS Institute, Inc., Cary, NC, 2000). Fisher's least significance difference (LSD) test was used to compare means ($P \leq 0.05$) (SAS© Institute Inc.). The Type III Sum of Squares analysis was performed.

Results and Discussion

Planting Depth

Through one season of growth and overwintering in the flat roof cravo, significant death occurred throughout both species of oak. *Q. rubra* was significantly more cold hardy than *Q. acutissima* pooled over all treatments. Northern red oak's (*Q.* rubra) native range is the eastern half of the United States from Arkansas up into central Ontario, Canada. The sawtooth oak (*Q. acutissima*) is native to Eastern Asia and has escaped into states from Louisiana and east, and north to Pennsylvania. Although sawtooth oak is usually more adaptable to adverse conditions than Northern red oak, this study indicates that the Northern red oak seems to be more cold tolerant.

Depth treatment played a major factor in mortality; seeds sown deep and planted deep suffered less mortality than any other treatment pooled over species. The plants in the deeply planted treatments would have had more stem and root insulation due to their planting depth. Sawtooth oak in two treatments, sown at the surface and then planted deep, or sown deep and then planted high, were the two tallest treatments. The sawtooth and red oak started deep/planted deep were the two shortest. This could be due the deep/deep treatments not emerging as early. Trees emerging sooner would be able to produce more photosynthate and thus grow at a faster rate than the deep/deep treatments. Trees pooled over species that were sown deep and upshifted high had significantly lower caliper than the planted at soil surface and upshifted deep.

In the root disturbance study *Tilia cordata*, at the $p<0.055$ level, had significantly greater caliper with four cuts N,S,E,W than with ½ inch of soil removed from sides and bottom. *Tilia,* therefore, had increased caliper when no roots were removed but the root ball was disturbed. There were no difference in height and dry weight and *Syringa* showed no significant differences due to treatments.