Chapter 13

Planting and Maintenance

James W. Consolloy

1. Introduction

Trees planted in the urban street setting are constantly fighting for their survival. Trees need sunlight, oxygen, water, and soil volume for nutrients and stability. As our urban population centers grow, technology and planning are needed to help establish trees in this environment. As new planting materials are developed and transplanting techniques are modified, it has become necessary to change our method of planting to meet the urban forests' challenge. Using the Princeton area as a model for planting and maintenance specifications in the Northeast will show both the seasonal considerations and problems involved in keeping a healthy and sustainable tree population.

Starting out with a management plan that fits into the community's budget (Chapter 8) is the first step needed to ensure a healthy tree community. The budget should cover costs for labor, materials, equipment, and maintenance needs. Today, newly developing communities that are still growing can most easily adapt to the latest specifications suggested for tree spacing, as well as introducing new mixes of trees. Older communities often do not have the luxury of providing an adequate growing space for shade trees and therefore are forced to crowd street trees between the curbs and sidewalks along the public right-of-way. This chapter also will consider both extremes and unusual situations faced by planners and municipal shade tree organizations in plant selection, shipping and unloading, planting techniques, transplanting, and early maintenance practices.

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2. Site Selection

A study showing the planting locations is the first step in planning the plant material list. Considerations should be given to various environmental factors that will impact the first 2 to 3 years of plant growth and establishment. Exposure to various environmental factors, such as the temperature, light, water, soil conditions, air quality, and biological and physical influences, should be assessed at each location. Urban areas are faced with many man-made influences as well. The following details some of the natural and man-made factors that in many cases have a direct correlation with a plant's sustainability:

1. Natural factors
   - Temperature (hardiness zone)
   - Water (flooding, annual rainfall)
   - Light (shade, partial, and full sun)
   - Air (percent 02, wind, and salt spray)
   - Soil (pH, percent sand, silt, clay, and organics)
   - Biologicals (native pests, diseases)
   - Physical (wind, lightning, and snow/ice)
2. Urban factors
   - Building vents, utilities
   - Drainage systems, irrigation
   - Reflection, streetlights, signs, and overhead wires
   - Exhaust emissions, blowers
   - Gas leaks, road salt, and oil spills
   - Heating, ventilation, and air conditioning
   - Imported pests on plants
   - Accidental scars, smoke/fire

2.1. Temperature and Hardiness

The hardiness rating according to zones (Chapter 11, this volume) has been generally accepted as one standard measure for a plant's ability to adapt to its environment. The temperatures apply mainly to the hardiness of the portion of the plant aboveground. The root systems are not as hardy as the aboveground portion and therefore should be protected during the winter seasons (Perry, 1989). Trees with fibrous root structures are especially susceptible to freeze-drying during the late fall and winter. When handling trees in the bare-rooted condition, it is very important to insulate the roots while transporting, and storing, during the planting process to ensure that the roots do not desiccate or the tissues freeze-dry.

Excessive heat from building ventilation systems will create artificial microenvironments having both negative and positive effects on plant growth. Aboveground blowers will create adverse drying conditions and eventually kill the plant, as will underground heat pipes; however, under some conditions plants that normally grow in more southern climates will survive close to these heat sources in the northern temperature zones.

2.2. Water as a Factor

Annual rainfall is certainly a consideration in plant selection. Drought tolerance, which is related to the plant's transpiration rate and the plant's ability to survive low-soil oxygen levels due to wet conditions, plays a key role during the first few years of establishment. See Chapter 11, this volume, for lists of drought-tolerant species and plants that will tolerate wet soil conditions (Flint, 1983).

In the urban environment, the rapid collection of rainfall through storm water drainage systems should be a prime consideration for the long-term survival of city trees. Likewise, the new installation of lawn basins to collect rainwater runoff may adversely affect existing trees dependent on that water. There also should be a careful design of impervious surfaces to allow large quantities of water to flow away from the tree pit (Whitcomb, 1987).

2.3. Light Considerations

Trees will dramatically respond to the presence or absence of light. This is a primary factor in deciding the species of tree to be planted. The successful growth of the tree will depend on the amount of natural light available. For example, American beech and sugar maple are climax forest trees that can live in dense shade under other trees and can be used in underplant aging street trees that are destined for replacement within the next 10 years. Less shade tolerant species, such as oak, hickory, and sweet gum, will not grow in a straight, upright fashion, but will lean toward the available sunlight, thus creating future problems for arborists to correct.

Night lighting, creating long days, can delay dormancy and result in continued elongation of vegetative shoots. *Betula, Catalpa, Platanus*, and *Tilia* were found to be the most sensitive to all sources of light. It was found in *Rhus, Koelreuteria*, and *Zelkova* that of the artificial light sources from most to least effective are incandescent, high-pressure sodium, metal halide and cool-white fluorescent and clear mercury vapor lighting (Harris, 1983). Reflected light from mirrored surfaces will scorch leaf tissue and result in distorted growth if the planting is too close to the source.

2.4. Air Quality

The natural effects of wind, salt spray, and wind-driven hail have a stunting and damaging effect on the growth habit of most tree species. Tree species with thicker leaves and bark and compact growth habits will survive under some of these conditions. Low-oxygen levels either as a result of higher elevations or the presence of higher levels of other gases will produce stunted growth or reduced chlorophyll production. The loss of the chlorophyll pigment will be one of the first signs of low-oxygen levels. Natural gas pipeline leaks and trapped sewer gas from unvented manholes will result in soil oxygen displacement.

Carbon monoxide exhaust from motor vehicles has chronic effects on vegetative growth. Avoid planting street trees too close to busy intersections. Exhaust from trucks that are forced to stop for traffic lights scorches and bums leaves and stems, with the inevitable loss of trees in that planting zone. Exhaust fans and large ventilation equipment, as well as steam and chilled water exhaust will have negative effects, the first signs of which are infestations of plant pests and diseases (Johnson and Lyon, 1979; Sinclair *et al*., 1989).

2.5. Soil Conditions

Preliminary soil tests prior to planting will eliminate future developmental problems with new plantings. Soil compaction, pH, percentage of sand, silt, clay, drainage, and the overall depth of the soil are important. Areas disturbed by construction are prime examples of overcompacted soils that need to be excavated and amended for increased porosity (see Chapter 10, this volume).

Topsoil for new plantings is frequently purchased from developers who are converting previously farmed land to new homes. These untested soils could contain root-feeding nematodes and residual herbicides.

When replacing street trees, if the cause of death is unknown, soil testing for gas leaks or road salt buildup and other contaminants could eliminate having to replace the tree for a second time. Soil volume, or the lack of, is a leading cause of street tree decline. There are design techniques for increasing soil volume under sidewalks and plazas using air-entrained soil mixes (Arnold, 1993).

2.6. Biological Factors

Planting trees in a new environment can present potential conflicts in terms of survival. For example, introducing European little-leaf linden into an area with high concentrations of Japanese beetles will add additional maintenance on those trees. Trees purchased from certified nurseries and planting resistant trees for the location will eliminate many future maintenance problems. Also, knowing what diseases are spreading into the area will help decide the plant selection.

2.7. Physiological and Morphological Factors

Tree location often determines future physical and structural problems. Will bicycles be locked to the trunks leaving scars? As the tree develops, will large trucks interfere with the branching? Will overhead wires result in severe pruning? Will snow and ice slide from rooftops onto the newly planted trees? Will low-branched trees be sandblasted during the winter deicing of roads and snow piled and pushed against the plantings? A preliminary study of the area, its usage, and the future impact on maintenance is very helpful (see Chapter 11, this volume).

3. Site-Specific Factors

The size of the planting space ultimately determines the tree's size and its ability to grow to maturity. Research has shown that there is a direct correlation between soil volume and crown size and sustainability (see Chapter 10, this volume). The depth of soil is not as critical as the total volume of the root zone (Bassuk and Trowbridge, 1989).

The crown size and growth habit must be considered when planting under utilities, close to building structures adjacent to roads and walks, and in competition with other vegetation. For example, planting trees with a multileader growth habit will allow for little future interference by overhead wires and minimal top pruning. Special purpose trees, widths of trees, and lists of tree species can be found in Chapter 11, this volume.

Longevity of a species is a frequently asked question of arborists and nurserymen. There are documented street tree plantings well over 200 years old (i.e., Stamp Act Sycamores, ca. 1768, planted along Nassau Street, Princeton, New Jersey), while others, planted in New York City 7 years ago, cease to live. The problem of surviving in harsh city conditions, regardless of a tree's genetic makeup, has been the subject of ongoing investigation. We know that certain popular, short-lived street trees, like the Callery pear and Norway maple, are still planted in large numbers despite the vast menu of other species. There also is a strong correlation between longevity and planting methods (Arnold, 1993).

The starting size for a street tree depends largely on the municipality's budget, and the total number of trees that can be planted with the resources available. Other factors to consider are survivability of certain tree species and planting times. The cost to plant a 2-inch caliper bare-root street tree can be as little as 40% of the cost to plant the same size balled and burlapped. This is partly due to the added labor costs for digging, handling, and shipping.

There are customized trees available in containers that work quite well if the planting job is delayed. From a maintenance point of view, containerized plant material is easier to handle and keep watered and can be planted at any time of the year. Bare-root trees must be installed without delay in order to ensure their survival.

4. Transportation, Care, and Handling

Care and handling of trees in shipment should follow the same guidelines as that of preserving perishable goods. Live plants need to be protected from desiccation and wind damage while being transported on open bed trucks. Branches of balled and burlapped trees should be carefully tied together before loading and bundles of bare-root trees wrapped prior to storage and shipment. Balled and burlapped trees are often stacked on flatbed trucks and trailers and then tied down and tarped. This practice has many advantages, including that of preventing desiccation of plant tissue and wind damage to buds, leaves, and other structures. Tree trunks should be padded when in direct contact with other hard surfaces, such as tree balls, headboards, and other trunks. Even the tie-down ropes must be padded to prevent any girdling effect on bark tissue.

Trees shipped in closed trailers are normally refrigerated and kept cool, dark, and moist. They will stay dormant under these conditions. However, if left under these conditions for too long, as with cross-country shipments, there may be signs of fungus growth on the plants, particularly with branches and evergreen shrubs that are tightly packed together.

4.1. Inspection

Upon arrival, plants should be inspected for broken and bruised roots, trunks and limbs. Balled and burlapped plants especially should be inspected for signs of rough handling, such as exposed sapwood from bruising, rope burns on the bark, damaged soil balls, exposed roots, and soil loss from torn burlap. All plants must be unloaded immediately. The plants will dry out quickly and the tied up portions of the trees will start to heat up if not untied. At this time, any broken branches can be removed. Reports of damaged plants must be filed with the shipping company and the seller as soon as the plants are unloaded. Pictures of the damage will be very helpful in recovering your losses.

If the trees are not ready to be planted, they should be spaced apart as they were at the nursery and kept in the upright position and watered frequently. When they are left lying on their sides, phototropism will take over and the terminal shoots will start bending toward the light. The terminal shoots of evergreens will start growing in this curved mode as soon as they are left in a prone position. When trees are planted with the terminal shoots crooked, it may take several growing seasons to correct this deformity. The other solution would be to prune the tops back to a lower terminally growing bud. The risk is that these buds may not show apical dominance. This is another advantage of planting trees that are dormant and not actively growing.

Nurserymen and landscapers in the past would "puddle" the roots of bare-rooted plants by dipping them in a slurry of mud and "heeling" the roots into sawdust or mulch hay while they were waiting to be planted. Today, nurseries have cold storage facilities and holding areas to protect the plants from extreme temperatures. This process helps to ensure the freshness of the trees being shipped.

Before planting bare-rooted trees, public works and landscape crews can use water gels that are available in most horticultural supply houses to protect the roots from desiccation. These water gel granules or powders, when added to water, swell to many times their size. They will adhere to the root fibers when the tree roots are dipped into a tub or trough of the solution. The gel will remain with the roots when planted allowing newly developing roots to absorb water from this source. The water gel granules can also be added to the backfill mix when planting or transplanting balled and burlapped and containerized trees.

5. When and How to Plant

Tree planting is most efficient when soils are "workable," neither too wet nor too frozen. In early spring when the frost disappears and the soil temperatures start rising above 40xF, the soil will begin to dry. Conditions are optimum for planting when the soil falls off the shovel or spade as it is backfilled into the tree hole. Likewise, in the late summer and early fall before the soil temperatures begin to decline, planting will be optimum. Trees will establish new roots more quickly when the soil temperatures are higher. This is an important aspect of fall planting, especially when planting evergreens. The sooner a tree sets roots in the fall, the less likely that it will be blown over by the winter winds.

When planting during the dry fall months, watering is critical so as to assure that the roots do not freeze-dry during the winter. Soils should be “settled in” around the rootball of a balled and burlapped tree and more thoroughly around the roots of a bare-root tree. This eliminates any voids and air pockets that may form. These voids often harbor insects and rodents that will feed on root tissue and nest during the winter months.

5.1. Soils: Native versus Amended

The probability of finding undisturbed native soils in urban planting locations is low, and therefore excavated materials should be examined, tested if necessary, and removed. Ideally, any native topsoils should be saved and stockpiled for use in contaminated sites for just such occasions.

Native soils contain important soil micronutrients and organisms necessary for good root development. Structurally, these soils should support newly planted trees and evergreens with compaction rates sufficient to stabilize the plant and keep it from slipping or leaning during periods of high winds. Higher density soils, that is, with more silt and clay particles, will “firm up” and keep plants from moving.

Native soils also contain detrimental organisms such as *Phytophthora* and root-feeding nematodes. Soil samples should be bioassayed prior to use. The enzyme-linked immunosorbent assay is one such test for the presence of harmful soil organisms (Smiley, 1994).

Artificial soils, if amended with the necessary nutrients and microorganisms, are quite effective in establishing new root systems. Because of their low density; however, they generally have a lower compaction rate and cannot give the same long-term structure as native soils that have higher proportions of silt and clay.

Trees that were planted in artificial soil mixes will settle in the tree pit as the organic matter in the mix starts to decompose. This will leave the basal root flare below grade, and in some cases the trees will be sitting in a depression. If this depression is filled back up to grade, it is very important to keep the fill material, in some cases mulch, away from the trunks where wood decaying organisms can destroy the root collar tissue (Fig. 1).

5.2. Planting Hole

One of the most important steps in tree planting is preparing the tree hole or tree pit. The hole size is based on the size of the root ball (balled and burlapped) or the root mass (bare root). The diameter of the hole should be two times (2×) the size of the rootball for a small to medium sized street tree and three times (3×) for larger and taller trees such as ash, elm, oak, locust, maple, and sycamore.

The depth of the hole is determined by the height of the soil ball (balled and burlapped) or the height of the root mass (bare root). Check the soil ball before planting and locate the top of the root mass by excavating some of the soil around the trunk. Follow the root flare from the trunk to determine whether the tree was transplanted with enough of the root system. Nursery-grown trees that are mechanically dug should be examined closely (Fig. 2). Keeping the top of the root mass slightly

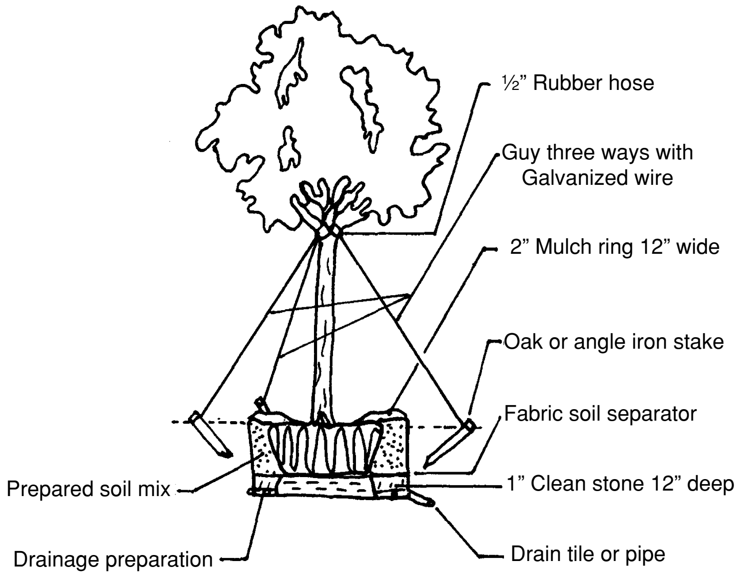

FIGURE 1. Guying and mulching detail.

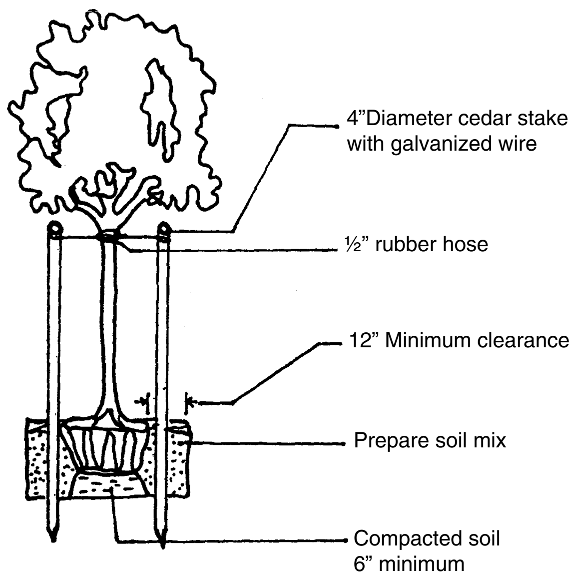

FIGURE 2. Planting and Staking detail.

above grade will ensure that the roots will have the right oxygen levels needed and that the bark tissue and the base of the trunk will not decay.

5.3. Pruning

There are two widely practiced methods of pruning young plant material following transplanting. The first method removes only dead or broken branches and, in the case of bare-rooted trees, torn roots and any root decay. The theory behind this method is to retain as much root and branch structure as possible and therefore the stored energy reserves.

The second method requires more precision pruning. Not only are the broken, decayed, and dead portions of the tree removed but the branching is also cut back, with several buds and some inner branching removed. The theory behind this method is to reduce the amount of vegetative growth that cannot be supported by the loss of root mass following transplanting. This is also the principle behind the cultural practices of the bonsai in containers and pollarding in some European cities to offset low-soil volume in confined urban settings.

It is an especially important practice to make clean, sharp cuts when pruning branches and roots. This will ensure proper tissue callusing, thus preventing disease formation at the wound entry sites. New roots form quickly from sharp cuts versus jagged, torn root structures. Arborists also recommend sanitation of the pruning equipment, including chain saws and power scythes to prevent the spread of bacterial, viral, and fungal diseases.

5.4. Fertilizing

Fertilization of newly transplanted trees is best carried out during the planting process. The incorporation of decomposed organic matter in the backfill mix still should be a part of the planting process. The addition of mycorrhizal spores in the soil mix adjacent to the root ball will "jump start" the rooting process to ensure increased root regeneration at the start. The spores can be applied either in a solution sprayed or poured on the outside of the root ball or using biodegradable packets placed in the backfill mix.

Granular fertilizers, such as 10–6–4 (50% organic nitrogen) or 20–12–8 (50% organic nitrogen), have been dependable formulations. The latter, higher formulation is used at half the rate, which amounts to 1/2 pound per 1-inch diameter of trunk size. The decreased volume of fertilizer can be labor saving when you have hundreds of trees to fertilize.

Water-absorbent gels incorporated in the backfill mix are an added assurance during drought periods when trees cannot be watered on a regular basis. As the gel crystals absorb water and expand, the increased water-holding capacity provides sites for newer roots to feed. These sites continue to trap water as it passes through the soil.

Granular wetting agents also ensure water penetration to the root zone and will decrease the initial surface runoff. If these wetting agents are not present in the upper layers of soil, adding a soluble wetting agent to water supplied from tank trucks will accomplish the same result.

Soluble tree fertilizers can be applied at any time provided that the nitrogen source is nearly 100% organic. These slow-release nitrogen formulations can be applied to newly planted trees in the fall without having phytotoxic effects or dramatically increasing the vegetative growth, which could delay the onset of dormancy. They are essential for continued root development that should continue throughout the dormant period.

The negative effects of increased vegetative growth during the late fall are manifest in continued stem growth, leaf retention, cambial growth, and consequently water movement in the young trunks. This can result in frost cracking of the basal trunks and branch breakage from early wet snowfall before leaf drop. Frost cracking will occur when the daytime temperature drops 40x at the bark surface within a few hours, before the water within the vessels can flow back to the root zone. These cracks will appear on trees with thin bark such as sycamores, maples, and fruit trees.

Recent evidence suggests that some soil amendments have had little effect on additional growth to the crowns of newly planted trees when compared to non-amended back-fill mixes (Gilman, 2004).

5.5. Bare-root Planting

The care and inspection of bare-root trees up until the time they are planted is critical to their survival. One distinct advantage in specifying bare-rooted trees is seeing the complete root structure before the tree is planted. Another advantage in using these plants is the ability to make sharp cuts at the ends of the major roots, increasing root regeneration at these sites. This should be the case with balled and burlapped trees if the digging crews used a sharp spade or loppers during the balling process.

Once the planting hole is prepared (Fig. 2), the tree can be positioned properly in the hole. Another advantage is being able to see the root flare and adjust the height of the root collar making it slightly visible above the soil line.

The condition of the backfill mix is best when "friable," meaning that it is dry enough to flow in and around the roots, displacing all voids and potential air pockets. Using water afterward will help to accomplish this important step in the planting process. Inspections of unsuccessful bare-root plantings reveal damaged roots when these air pockets are not eliminated. The finer roots and root hairs often are dried up or rodents have found shelter and food among the roots during the winter months. The bark of fruitwoods, maples, and some needled and broad-leafed evergreens is very attractive to rodents and rabbits as the winter food. Again, roots left to freeze-dry over the winter will result in crown dieback, which will appear in the late spring and the early summer.

5.6. Balled and Burlapped Planting

Trees dug with a soil ball, either by hand or mechanically, will have a higher survival rate than bare-root trees. The added soil will protect the root structure during the transplanting process. Balled and burlapped trees can be successfully maintained for longer periods aboveground before planting. The soil ball adds stability to the tree and retains water to ensure against root tissue desiccation.

Either hand- or machine-dug trees with calipers of 2 to 32 inches are the easily handled sizes for transplanting and have shown satisfactory survival rates (Kressel and Burck, 1995). They also are much easier to handle and maintain at those sizes than larger ones. Balled and burlapped trees in the 2 to 3 1-inch caliper range will establish new root systems, resume vigorous growth faster, and can reach an environmentally beneficial size faster than larger trees (4 to 12-inch caliper) planted at the same time. The time required for trees to regain pretransplanting growth is approximately 1 year for each 1-inch caliper (Watson, 1996). Young trees will need less post-transplant support (i.e., straightening, staking, and guying).

Natural untreated burlap, sisal, and manila rope on hand-dug soil balls are decomposed within weeks by soil microbes, allowing easy root penetration into the surrounding soils. Machine-dug trees are placed in a burlap liner inside a wire metal basket. At the time of planting, the wire basket should be removed or cut away once the tree is in position. In all cases, the burlap and rope should be removed or folded down away from the top of the soil ball. If left in place, the burlap will interfere with proper water uptake and can retard basal root development. Leaving the top lacing of rope around the trunk will result in girdling and the eventual death of the tree (McNeil *et al.*, 1982).

As the burlap is removed from the top of the soil ball, inspect the root crown or top of the root mass to make sure it is visible. If the root crown is not visible, the tree was planted too deep in the nursery and therefore not dug to a proper depth. Most likely, many of the bottom feeder roots were left at the nursery and not recovered with the soil ball. This is a leading cause of crown dieback and goes unnoticed by many plantsmen.

Balled and burlapped trees are best handled by the root ball and not the trunks. Trunk bruising is a common cause of wounding and bark dieback, leaving entry points for disease and insect attack. The use of a hydraulic ball grabber or a set of steel forks will safely handle the smaller-size trees, as well as help position the tree within the planting hole.

Trees that are skinned or bruised through rough handling will show signs of bark dieback within a few months after planting. At that point, a typical maintenance procedure by arborists called *tracing* will allow for faster wound closure and callusing of the cambial tissue. This is normally done with a sharp utility knife, cutting or tracing around the wound just into the live tissue, and then removing the dead bark from the sapwood layer (Conover, 1977).

5.7. Container Planting

A recent method of growing trees in containers is referred to in the nursery industry as the "pot-in-pot" method. The only difference from the original method of container growing is the placement of the containerized plants into other containers that are set in the ground in rows and connected to the proper feeding and drainage systems. The plants are easily removed from the stationary pot and fitted with a new one when sold. The advantages of this method of production are controlled growth of roots and stems, stable upright growth, and more importantly ready availability of the plant at any time of the year. Not all tree species grow well in a container environment, so there are some drawbacks to this method of tree production. Transplant shock is lessened when using containerized plants because the root and shoot growths are relatively balanced (Flemer, 1972). However, they are irrigated on a regular basis and the new shoot growth can be very soft and subject to wilting when moved from the containers. In such cases, it is necessary to remove some of the soft tissue growth and maintain a regular watering schedule until the root system adapts to the new soil conditions.

Container plants have been grown in artificial soils which are less dense and will drain readily. Therefore, it becomes necessary to dig the planting hole twice as wide and at least 6 inches deeper than the container soil ball. Break up the sides of the hole to allow the roots to penetrate the native soils more easily. The soil under the plant should be tamped to prevent settling or shifting over time.

When the plant is removed from the container, examine the roots carefully. If they formed a solid mass around the inside of the container, trim approximately 2 inches off the roots and break apart the root mass evenly. If the root mass is minimal, make four or more even slices 1 inch deep around the root ball before planting. Another very important procedure is to break down the "shoulder" of the root ball at the top to allow water penetration into the top of the ball.

Use a light backfill mix of about 25% peat moss or leaf compost to 75% soil. Never plant containerized plants in waterlogged soils because the container soil mix will act as a sink and wick the surrounding water. Look for a better-drained site.

5.8. Large Tree Transplanting

Moving larger trees (4- to 12-inch caliper) is accomplished efficiently using tractor- or truck-mounted mechanical tree spades. The larger spades typically can move up to an 8-foot soil ball with little effort. One of the benefits of this method is minimal root, trunk, and site disturbance, since the tree is only handled one time. This can be a large savings in terms of time, labor, and equipment. Two people can complete the entire operation with only one piece of equipment to dig, transport, and plant the large trees.

Some of the disadvantages are digging in shale- and rock-littered soils, crushing and tearing of large framework roots when caught between spades, and planting the spaded root ball into a predug hole where a "plug" of soil was previously removed. In heavier clay soils, these predug holes have glazed and compacted sides that can form barriers to future root penetration and proper development.

To ensure a better planting environment in poor soils, use a backhoe to predig a hole larger than the maximum size of the tree spade and backfill it with an improved soil mix. Compact the new mix in 2-foot intervals as it is added using the back of the hoe bucket until the hole is filled 6 to 12 inches above existing grade. Allow the site to settle and add water if needed. After settling has occurred, remove the soil "plug" to match the size of the root ball being transplanted.

At the time the new tree is being set into the hole, the addition of root-building material applied to the walls of the hole is very beneficial. There are many new root-building supplements available from horticultural suppliers: water gels, wetting agents, ectomycorrhizal fungal spore solutions, liquid chelated micronutrient compounds, and humic acids. These products can be used alone or mixed with a soluble root fertilizer and sprayed or injected into the root zone area. All these products will help reduce transplant shock and promote faster root growth and establishment. Most landscape contractors and tree-moving companies include these products in their transplant costs.

6. Staking and Guying

All newly transplanted trees should be staked or guyed for a minimum of 1 year or until the tree has developed its own support roots. Maintenance of the stakes and guy wires is minimal if properly installed. Shade trees with calipers up to 3 inches planted either bare root or balled and burlapped will require two stakes. In sandy soils and windy sites such as shorelines the trees will require three stakes. An 8-foot stake is minimum length for shade trees and is driven into the soil 2 feet. For smaller flowering trees and small bare-root shade trees less than 2 inches in caliper, a 6-foot stake driven into the soil 2 feet will suffice.

Trees larger than 3 inches in caliper need a minimum of three guy wires. Lighter, 16- to 14-gauge galvanized steel wire will support trees in the 3- to 4-inch caliper range. Use of 12-gauge galvanized steel wire for trees with excess wind resistance or height is recommended for support and is cost-effective. Larger-caliper trees with large crowns will require more elaborate guying techniques. Additional guying wires may be required and use of 1/8- to 9/16-inch aluminum aircraft cable with 3/8- to 9/16-inch galvanized steel turn-buckles for tensioning, again depending on the site conditions, will support trees up to 12 inches in caliper. The use of "deadmen" instead of stakes will be needed to support these heavier structures (Fig. 2).

Maintenance of the guys over several years is necessary because of the slower reestablishment rate of larger trees. To assure the trees' stability, use the turnbuckles to determine whether the tree can stand on its own. Lessening the tension on all guy wires allowing for minimal slack on each one and watching for any shift in the tree's position will determine how much longer the guying is needed. If any of the wires or cables start to tighten on their own, then it is too soon to remove them.

Proper trunk protection is also needed at points along the trunks where wires and cables are attached. Materials range from soft rubber hose, polypropylene chain, and sling material made from plastics to burlap-wrapped blocks of wood tied around large trunks for cable protection. Regular inspection during the growing season will prevent any girdling from taking place. Retensioning of the wires is critical at this time. Girdling occurs more readily in soft wooded trees and conifers than it does in oaks, ash, and maples.

Trunk protection using paper or burlap tree wrap will help prevent insect damage and vandalism. The wrap is applied in a spiral overlapping pattern and tied with plastic garden tie. There are plastic spiral basal trunk wraps available that are useful in areas of high rodent or rabbit populations. All wraps should be regularly checked for any signs of girdling; when they are removed, any insect eggs or nests under the wrapping should be identified and eliminated at that time.

7. Mulching

The single-most important benefit of mulching is water retention; along with weed retardation it is a valuable step in tree planting. A 2-inch layer of mulch will save on additional irrigation and will trap needed rainfall before runoff can occur.

Overuse of mulch has negative effects on plant growth and establishment. Large quantities of mulch piled up around the base of the trunk will harbor wood-decaying organisms that damage bark tissue and upper root collar tissue and can eventually cause plant dieback. Mulches should be properly aged before using in the landscape. New mulch will render nutrients (specifically nitrogen) unavailable for the plant. Excess mulch also will invite unwanted rodents during the winter periods. They will feed on the bark and cambial tissue at the base of the trunk, totally girdling the tree below the mulch line.

Therefore, it is recommended that the mulch does not come in contact with the trunk of the tree. As the tree matures, it is a healthy sign when the upper root flare of the tree is exposed to the air. Mulch rings can be extended but should not cover the buttress roots (Sinclair *et al.*, 1989).

8. Watering

Adding water to the backfill mix as it is added into the planting hole is extremely important and will ensure sufficient contact between the root ball and the adjacent soils. It will settle the soil around the root ball, helping to eliminate any voids or crevices created during the backfilling process. Normal rainfall in the Northeast will not suffice during the summer months, and supplemental watering is critical during the first year of establishment.

Using a wetting agent in the tank mixture and adding granular water gels to the backfill mix will add to the efficiency of the watering process. The wetting agents help reduce surface tension on water droplets so that they can penetrate hydrophobic conditions on the soil surface and the burlap. The granular water gels will swell up when they come in contact with water in the soil and act as water-holding sites for the new feeding roots. Other products on the market not only will enhance soil penetration, but also add to the efficacy of biological chemicals that will penetrate the root tissue and aid in absorption of systemic pesticides.

Water bags and plastic rings that hold and release water slowly have proved to be a very effective means of watering newly planted trees. These structures can be used during drought periods and then stored for future use.

Watering is most effective if done either early in the morning or late in the day to prevent wilting. The evaporation rate is minimal during these cooler periods. Many municipalities in urban areas have water restrictions during the summer months but allow some watering at night. Most will allow tree watering by tank if bags and mulch rings are in place.

Adding nutrients and fertilizers to the water tank mix in the late summer or early fall will save an additional maintenance step. All plants should be thoroughly watered before the ground freezes. Many young trees die in their first year because of the winter root losses from desiccation.

Determining how much to water depends entirely on the available water-holding capacity of the soil within the root zone and the tree's water needs. Soils with good tilth that are friable (crumbly) and well structured have the best water-holding capacities and infiltration (Kelsey, 1996). Strategically placed rain gauges and soil sampling probes will help assess how much additional watering is needed during periods of drought.

9. Tree Care and Maintenance

Trees require four-season maintenance and inspection to ensure survivability. A typical tree-preventive maintenance schedule will involve a program dedicated to total plant health care. The size and nature of the municipality will determine how to structure the plant health care program. For small towns, volunteer groups can adopt individual streets, assist municipal works departments with the summer watering, and watch for vandalism. As the areas increase in size, the municipality can subcontract some of the pruning and watering, especially if the trees were planted by subcontractors (see Chapter 19, this volume). Large cities will need to staff full-time arborists and landscape crews to look after their larger investment of shade trees. And all municipalities need to share common problems with neighboring municipalities at annual regional shade tree meetings.

The first 3 years are critical for the establishment of newly planted trees. A plant health care program should include all newly planted trees each year as they are recorded in the inventory. The plant health care program should include integrated pest and plant management monitoring (see Chapter 18, this volume) by a trained individual who will be responsible for the reporting and treatment of all tree and environmental problems. Most tree maintenance companies offer a full plant health care program and the services of a monitor or field scout who can report to the municipality's public works director or department superintendent. The monitoring period should extend from early April through late November. During this period reports should be filed weekly and recommendations for treatments discussed on a regular basis.

The landscape crew should take full responsibility for the maintenance of all trees newly planted over the past 5 years. After that, they should be included in the scope of work for the arborist crew. During the initial 5-year period the landscape crew's scope of work should include: tree straightening; checking stakes, guys, and wraps; weed control; pruning; fertilizing; remulching; watering and insect and disease control; and if necessary tree replacement. Insect and disease control is normally coordinated with the integrated pest management monitor and the arborist crew to minimize the use of pesticides.

References

Arnold, H. F., 1993, Sustainable trees for sustainable cities, *Arnoldia* **53:**3.

Bassuk, N., and Trowbridge, P., 1989, Urban islands, *Landscape Architec*. **79:**130–131.

Clark, and Rapauno Associates, 1965, Planting Specification for Princeton University, not published.

Conover, H. S., 1977, *The Grounds Maintenance Handbook*, New York: McGraw Hill, p. 108.

Flemer, W. III, 1972, Growing street trees in containers, *Am. Nurseryman,* 136:75–83.

Flint, H. L., 1983, *Landscape Plants for North America*, Wiley-Interscience, Purdue University, IN.

Harris, R. W., 1983, *Arboriculture: Care of Trees, Shrubs, and Vines in the Landscape*, Prentice-Hall, Englewood Cliffs, NJ.

Johnson, W. T., and Lyon, H. H., 1979, *Insects That Feed on Trees and Shrubs*, Cornell University Press, Ithaca, NY.

Kelsey, P., 1996, Diagnosing nutrient deficiencies in hardwood trees, *Grounds Maintenance* **31**(6):28–33.

Kressel, S., and Burck, S. (eds.), 1995, From the Proceedings from *ASIA Urban Street Tree Planting Symposium,* Boston Society Landscape Architects, Boston, pp. 17–31.

MacDonald, J. D., Costello, L. R., Lichter, J. M., and Quickert, D., 2004, Fill soil effects on soil aeration and tree growth, *J. Arboric*. **30**(1):19–27.

McNeil, R. E., Fountain, W. M., and Witt, N. L., 1982, Tree decline in the landscape when the trees were dug BNB, in *Proceedings of the Urban Trees and Forest: Pest Management Problems, Needs and Prospects*, (unpublished).

Perry, T. O., 1989, Tree roots: Facts and fallacies, *Arnoldia* **49**(4):3–29.

Sinclair, W. A., Lyon, H. H., and Johnson, W. T., 1989, *Diseases of Trees and Shrubs*, Cornell University Press, Ithaca, NY.

Smiley, E. T., 1994, *Plant Diagnostic Report–Princeton University*, Bartlett Tree Research Laboratories, 13768 Hamilton Road, Charlotte, NC 28278.

Watson, G. W., 1996, Tree transplanting and establishment, *Arnoldia* **56**(4):11–16.

Whitcomb, C. E., 1987, *Establishment and Maintenance of Landscape Plants*, Lacebark, Stillwater, OK, pp. 251–262.

Other Suggested Reading

Birchell, R. S., 1996, Saving trees—Conservative construction, *Grounds Maintenance* **31**(5):48–54.

Cranshaw, W., 1997, The pros and cons of biological control, *Grounds Maintenance* **32**(3):44–48.

Cranshaw, W., 1997, The pros and cons of biological insecticides, Part II: Microbials, extracts and IGRs, *Grounds Maintenance* **32**(4):45–56.

Fraedrich, B. R., 1995, *New Concepts in Tree Planting*, Bartlett Tree Research Laboratories Bulletin, Charlotte, NC.

Fraedrich, B. R., 1995, Solutions to tree—sidewalk conflicts, *Tree Sci*. (Winter) **1995:**3–6.

Gilman, E. F., 2004, Effect of amendments, soil additives, and irrigation on tree survival and growth, *J. Arboric*. **30**(5):301–310.

Grabosky, J., and Gilman, E., 2004, Measurement and prediction of tree growth reduction from tree planting space design in established parking lots, *J. Arboric*. **30**(3):154–164.

Herms, D. A., 1996, Growing growing gone, *Am. Nurseryman* **184**(7):52–57.

Hummel, Jr., N. W., 1995, Assess soil conditions on site, *Grounds Maintenance* **30**(6):22–28.

Percival, G. C., 2004, Evaluation of physiological tests as preditors of your tree establishment and growth, *J. Arboric*. **30**(2):80–91.

Pill, W. G., 1997, Filling the voids, *Am. Nurseryman* **185**(12):30–37.

Roger, M., 1994, Trees need fertilizer, too, *Grounds Maintenance* **29**(3):74–78, 95.

Ruter, J. M., 1996, Regulating growth of woody ornamentals, *Grounds Maintenance* **31**(5):42–46.

Shigo, A., 1988, *A New Tree Biology: Facts, Photos, and Philosophies on Trees and their Problems and Proper Care*, Shigo and Trees, Associates, Durham, NH.

Shigo, A., 1991, *Modern Arboriculture: A System Approach to the Care of Trees and their Associates*, Shigo and Trees, Associates, Durham, NH.

Shoup, S., Reavis, R., & Whitcomb, C. E., 1981, Effects of pruning and fertilizers on establishment of bareroot deciduous trees, J. *Arboric*. **7**(6):155–157.

Smiley, T. E., and Shirazi, A. M., 2003, Fall fertilization and cold hardiness in landscape trees, *J. Arboric*. **29**(6):342–346.

Smiley, T. E., and Shirazi, A. M., 2003, Fall fertilization and cold hardiness in landscape trees, *J. Arboric*. **29**(6):342–346.

Tubesing, C., 1997, Another look at first rate plants, *Am. Nurseryman* **186**(1):62.

Urban, J., 1989, New techniques in urban tree planting, J. *Arboric*. **15**(11):281–284.

Weddle, A. E. (ed.), 1983, *Landscape Techniques*, Van Nostrand Reinhold Company, New York, pp. 147–157, 183–201.

Weiner, M. A., 1992, *Plant a Tree*, Wiley, New York, pp. 53–74.