ATTAINING ROOT:CROWN BALANCE IN LANDSCAPE TREES[1]

by Gary Watson

'Root:shoot ratio' is the term that is often used to describe the relationship between the below- and above-ground portions of plants. It is defined as "the total root system mass divided by the total shoot mass, usually on a dry weight basis" (17). This description of the physical relationship between below- and above-ground parts of plants does not adequately describe the important physiological aspects of the relationship. The term 'root:crown balance' is more complete. In this paper, root:crown balance is considered as the relationship between water and mineral absorption by the root system, and utilization by the crown. The term 'balance' describes the delicate physiological equilibrium between the root system and the above-ground parts of the plants more completely. 'Crown' is used because it describes the entire canopy of large landscape plants more appropriately than 'shoot'. The root:shoot ratio is one component of the root:crown balance.

The root:crown balance is affected by both physical and physiological changes. Physical disruption of the balance is possible by removal of either roots or branches. Physiological changes such as reduced soil moisture uptake, constriction of vascular transport, and excessive transpiration rates can also disrupt the balance. Since reduction of the water supply will have the most immediate and serious effects, reducing the root:crown balance (loss of roots or root function relative to the crown size) has far more serious implications than increasing it.

Root:crown balance is under both genetic and environmental control. When genotypes of Siberian elm (*Ulmus pumila*) were compared, seedlings from arid climates had higher root:shoot ratios than did those from more mesic climates, when both are grown under identical conditions (4). Cassava (*Manihot eschlenta*) clones also show large varietal differences in the root:shoot ratio developed under identical conditions of culture (3).

Variations in environmental conditions can also affect the root crown balance, even within the crown of a single tree. von der Heide-Spravka and Watson (18) showed that that the north side of littleleaf linden (*Tilia cordata*) had 26 percent more root surface area per unit leaf area than the south side.

Common arboricultural practices also alter the root:crown balance. Transplanting, root pruning along uplifted sidewalks, and root damage resulting from construction activities are all examples of deliberate root system reduction. Urban trees are commonly planted where development of the root system is limited by the quantity and quality of the soil, and risk of elevated transpiration and water stress is high (7), thus decreasing the root:crown balance.

Root Loss as a Result of Transplanting

Perhaps the most extreme case of root:crown imbalance occurs in transplanted trees. Over 95 % of the root system can be lost when trees are dug from the nursery using standard methods (22), and the capacity to absorb water from the soil is proportionately reduced. Roots can only absorb water from soil into which they have proliferated (8). Consequently, the water contained in the soil outside of the rootball is largely unavailable to a transplanted tree until the root system has grown into it.

It can take as long as 7 weeks (16) for new roots to be initiated from the callus formed after a root is cut. It can be as long as 13 weeks before the regenerated roots absorb measurable amounts of water from the soil outside of the root ball, and at least 20 weeks until soil moisture is absorbed at

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similar rates from the root ball and backfill soils (Watson, unpublished data).

Barnett (1) showed that 4 weeks after planting, the water supply of privets was only 4 days. As the root system grew at a greater rate than the shoots, the soil moisture supply increased to 11 days at 21 weeks after transplanting. The water supply of newly transplanted trees is also just a few days when transpiration is high (Watson, unpublished data), but the duration of drought stress is more prolonged because it takes longer to replace the larger root system that was lost.

Leaf size and growth rate are good indicators of stress in transplanted trees. Bud expansion is regulated by the availability of water, and the number of leaves is predetermined during the previous season while the bud is being formed. The first season after transplanting, the leaves tend to be small, since the bud expanded under stressed conditions, while the number of leaves is high because the bud was formed under unstressed conditions (Figure 1). The second season, the number leaves is reduced since a smaller bud was formed when the tree was stressed, but the leaves may be larger, because the reduced number of leaves and partial regeneration of the root system has created a more balanced plant with less stress during bud expansion. As the root system expands each year, top growth will continue to increase. Only when the root system has grown to its full size will normal crown vigor return. Data from smaller trees (21) and field observations of larger transplanted trees, indicate that under Midwestern conditions, the period of reduced vigor following transplanting will last approximately 1 year for each inch caliper. The reduced vigor may not be obvious during the last few years, particularly on larger trees, but it is still measurable.

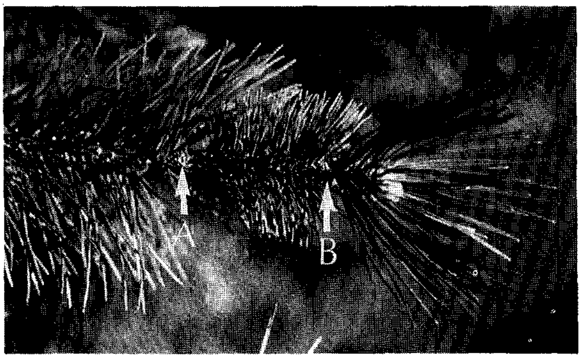

Figure 1. Pine branch showing pattern of reduced growth following transplanting. Growth the first year after transplanting (A-B) consists of numerous small needles since bud was formed under unstressed conditions but expanded under stressed conditions. The second year after transplanting (right of B) there are fewer needles because stress during bud formation resulted in a smaller bud, but the needles are larger because the partially regenerated root system and smaller number of needles combine to reduce stress as the needles were enlarging.

Root Loss from Construction Damage

It is usually obvious when excavation or utility trenching severs major roots at a construction site. Substantial root loss almost always results in crown dieback within a few years. Unfortunately, trees lost from construction damage are soon cut down and forgotten. The remaining trees offer no reminders of how fragile the trees really are. Occasionally a tree will survive the damage because of unusual or unknown circumstances. These 'exceptions to the rules' often provide a false impression of how seriously construction disturbance can impact trees, and the same mistakes are made over and over again.

Root damage also occurs indirectly when the soil is disturbed. Compaction restricts the necessary movement of water and air through the soil, and increases resistance to penetration by the growing root tips. The result is fewer roots in the soil to absorb the available water and nutrients.

While nursery-sized trees seem to be able to tolerate the loss of over 95 percent of their root system, large trees seem to be less tolerant of severe root loss. Large tree intolerance to root loss may be due, in part, to lack of regular watering after the root loss occurs. The need for frequent watering of large trees with root damage is not as well recognized as it is for newly planted trees, though the circumstances are very similar. Water is often unavailable on a site that is under development until it is near completion. By then it may already be too late. At one year per inch caliper to complete the replacement of a major root loss, these large trees may require judicious watering for decades. Considering the restricted root spaces on urban lots in comparison to the natural root-spread of trees, the root system may never be able to redevelop full size, and supplemental irrigation may be required for the life of the tree even under moderate conditions.

Increasing Crown Size

Forcing the crown to grow excessively through heavy fertilization may be harmful. Root density and stored carbohydrates of white oaks (*Quercus alba*) over 24 inches in diameter can differ with root environment and fertilization practices. Three situations were compared:

- Lawn trees receiving no supplemental fertilization (chlorotic with no fertilization and average to slow growth)
- Lawn trees that had received supplemental nitrogen fertilization by a commercial arborist each spring for at least 3 consecutive years (declining prior to fertilization and green with above normal growth when sampled)
- Woodland trees whose nutrients were derived from the natural decomposition of organic matter (green with normal growth)

Very low root densities were associated with both lawn situations when compared to the woodland trees (Figure 2). Chlorotic lawn trees had concentrations of stored carbohydrates similar to the woodland trees, while green fertilized lawn trees did not.

It is sometimes contended that fertilization will

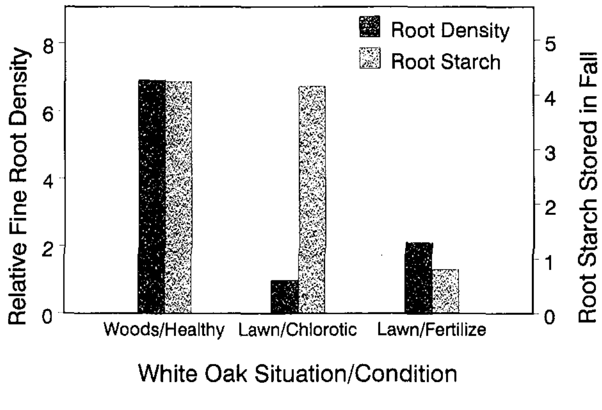

Figure 2. Root development and stored carbohydrates of trees in varying conditions and nutrient regimes.

lead to greener, larger leaves and increased carbohydrate production, which then would provide increased carbohydrate supply to the roots and increase root growth. This reasoning assumes that carbohydrates are in short supply in stressed and declining trees. The chlorotic lawn trees had high levels of stored carbohydrate available. Root development was poor because of soil conditions and grass competition. Roots are a major site of utilization of carbohydrates. If the root system is limited, either by major loss or restricted development, consumption of carbohydrates in the tree as a whole will be reduced. Carbohydrate reserves may actually be elevated even a with limited crown size or photosynthesis rate. A similar increase in concentration of stored carbohydrate was reported in trees after a year of post-transplanting stress (20).

Increased crown development did not lead to better root development in the fertilized lawn trees. Increased shoot growth of radiata pine (*Pinus radiata*) and red maple (*Acer rubrum*) due to high soil fertility also resulted in a lower root:shoot ratio (9,10). Similar effects have been shown in meadow plants (11) and turfgrass (2). A low level of fertility leads to the best balance between roots and crown (10).

Restoring Root:Crown Balance

Roots will naturally develop to the full extent that is possible in the existing environment - poor soils are associated with poor root development. Root profiles everywhere demonstrate this phenomenon. The best condition for root growth usually occur near the surface, but roots will proliferate extensively at greater depth if favorable soil layers are present. When the root environment can be improved, increased root development will follow. If the root environment is of high quality, more roots can be concentrated into a relatively small soil space. A tree can live long and grow large only if adequate water and nutrients are available from the soil. A small volume of high quality soil may be equal to a large volume of poor soil.

Mulching. The easiest and most effective way to improve the soil environment is through the use of mulch. It is not 'high-tech' or an 'overnight remedy', but it imitates nature and the scientific literature has reported its effectiveness in improving root development and plant vigor for nearly a century. Mulch eliminates grass competition, helps retain soil moisture (Figure 3), moderates soil temperature fluctuations, and adds organic matter to the soil. Under turfgrass, soil dries out (high Soil Moisture Tension {SMT}) very rapidly between rainfall events, while mulched soil remains very moist (low SMT) throughout the entire summer (Figure 4).

An 2 m (8 ft) circle of mulch can quadruple the root development of newly planted trees (5). In the top 5 cm (2 in) of soil the difference can be as much as 15-fold. These increases in root development lead to significant increases in growth of the crown.

Mulch has also been shown to increase the fine root density of established trees (6,19). Roots often grow in the mulch itself, if it is at least a few inches thick, increasing the total surface area of the root system (Figure 5), even if the lateral spread of the root system is restricted. Over a period of 3-5 years, soil characteristics such as bulk density and moisture content are improved by mulching (6).

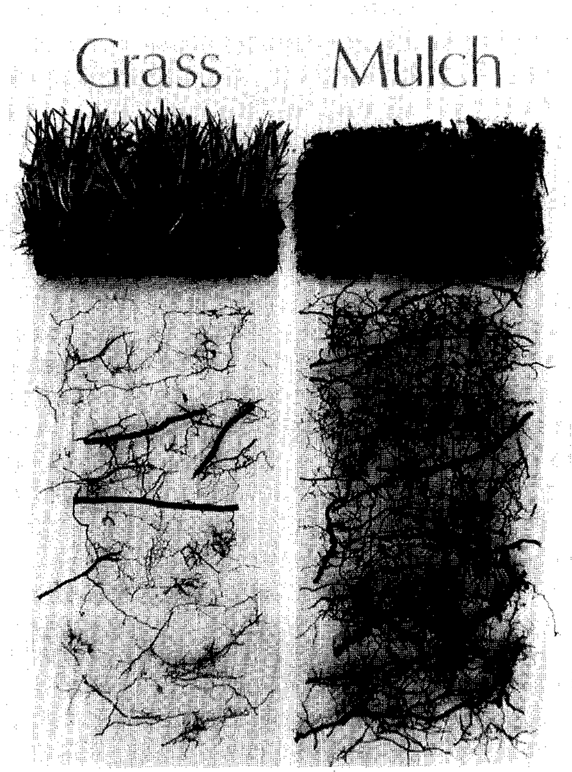

Figure 3. Sugar maple root development is reduced when lawn is present.

Aeration. Mechanical soil aeration has shown mixed results. Smith (13) found that drilling aeration holes in the soil stimulated tree growth nearly as much as fertilization. More sophisticated equipment now available may not be any improvement over the old-fashioned drill. Using compressed air technology, Smiley (12) found little improvement in soil aeration, bulk density or root development, but did measure a small (non-significant) increase in crown growth the second season after treatment (personal communication).

Soil Replacement. Zu (25) found that both root

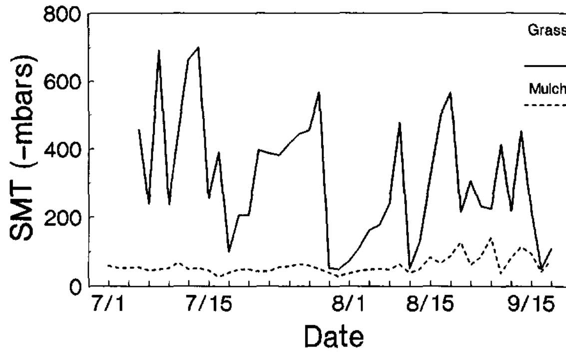

Figure 4. Soil under turf dries out rapidly between rainfall and irrigation events (high soil moisture tension [SMT]), while soil at the same depth under mulch stays evenly moist.

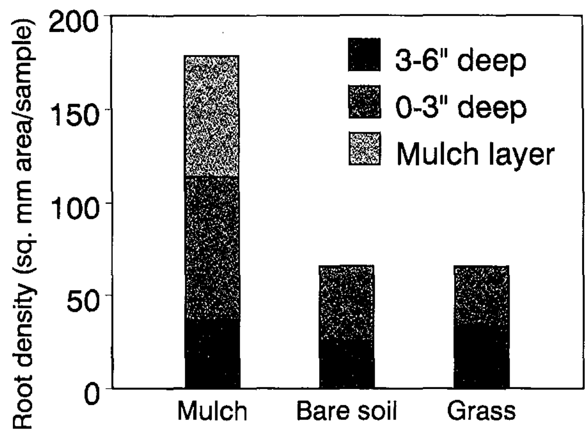

Figure 5. Root development is increased in the soil underneath mulch while the mulch itself can act as additional rooting medium.

and crown growth of declining ancient trees could be increased by laboriously replacing portions of the poor soil in the root zone with high quality soil, being careful not to damage the major roots. Density of root tips was increased 450 percent in the new soil, and twig growth was increased 60 percent. The labor involved in this method would make it prohibitive as a practical treatment.

Preliminary trials of soil replacement techniques at the Morton Arboretum are also encouraging. A backhoe was used to dig trenches around large white oaks, oriented like the spokes of a wheel around the hub. This arrangement minimized root damage, but some roots were severed. Roots proliferated into the highly organic replacement soil within the first year and continued to increase in density through the second year. Measured root densities were four times higher in the replaced soil than in the surrounding unaltered soil. This research will continue for several more years.

Modern equipment is available in Europe for soil replacement treatments. Woodtli (24, personal communication) reported improved root and crown growth as a result of partial soil replacement around trees.

Reducing the Crown. Crown reduction has become the standard arboricultural method of compensating for root loss. The purpose is to reduce transpiration and water stress, though no research has been published to demonstrate the effectiveness of this technique on mature trees. The transplanting literature is inconclusive on the value of pruning to reduce the crown. Physiological responses of the plants apparently interfere with clear-cut results.

Gibberellin biosynthesis-inhibiting growth regulators (i.e. paclobutrazol) have primarily been used to reduce twig growth near utility lines, and have not been fully explored as a tool for maintaining root:crown balance. In experiments with seedlings where the growth regulator is applied only to the leaves, root development can be stimulated while top growth is controlled (14,15,23). The potential is great, particularly if application by soil injection is perfected.

A greater focus on the whole tree is needed in arboriculture. What is done to one part of the tree affects the rest of it. A sound understanding of the entire tree from leaflet to rootlet, and its interaction with the environment will lead to more effective culture and maintenance of trees.

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ABSTRACT

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Increasingly the green industry is turning to integrated pest monitoring, application of short-residual or pest-specific products, and resistant plants. Horticultural oils are an important part of this trend. Horticultural oils were reformulated in the early 1980's, making summer applications more feasible. SunSpray Ultra-Fine Spray Oil is an effective pesticide with low leaf-burning potential. However, researchers must document its safety for nursery stock before many nurserymen will incorporate it in their summer pest-control programs. We developed an experimental procedure testing repeated applications of a 2 percent formulation of SunSpray 6E Plus for phytotoxicity on 52 taxa of nursery trees. In Maryland, many insect pests are active from May through August. Since these are the primary months of damaging insect activity, we chose these months to evaluate potential phytotoxic burn. Our conclusion is that 2 percent summer oil applications are safe for use on nursery stock to control insect and mite pests.