# SIGNIFICANCE OF ROOT SEVERANCE ON PERFORMANCE OF ESTABLISHED TREES[1]

by W. Douglas Hamilton

**Abstract.** There are many factors to consider when severing the roots of established trees. Factors governing root growth are discussed. Acceptable survival following severe root severance is interdependent with the condition of the top. It is important to know the location of various kinds of roots—large lateral, sinker, heart, non-woody. Key factors to successful results from severe root-pruning include: a tree species with adequate vigor, adequate moisture in the root area, healthy carbohydrate reserves, proper timing in climates with temperature extremes and knowing how to judge a tree that should not be severely root pruned. Many landscape trees appear to have a wide tolerance to root removal.

**Résumé.** Il a plusieurs facteurs à considérer lorsque les racines d'arbres à maturité doivent être endommagées. Les facteurs influençant la croissance des racines sont discutés. Une bonne survie d'une arbre après des dommages aux racines est dépendante de la condition de la cime. Il est important de connaître l'emplacement des divers types de racines - les racines primaires, secondaires et les radicelles. Les facteurs-clés afin d'avoir des résultats positifs après des dommages aux racines incluent: une espéce d'arbre avec une bonne vigueur, une humidité adéquate dans la zone racinaire, de bonnes réserves d'hydrate de carbone, le choix de la période appropriée dans les climats avec des températures extrêmes et savior reconnaître les arbres dont les racines ne devraient pas être endommagées. Plusieurs arbres d'ornement semblent avoir une grande tolérance à la taille des racines.

Several questions about tree roots have been dealt with in the past few years: pest problems, sidewalk-curb breaking and some relating to how and where they grow. To my knowledge, the question of severity of root removal has not been addressed. There is little question that root loss affects tree growth, appearance, and stability. But how significant are the effects and are there guidelines for management? There is a need to adjust our standards of expected performance of established trees as a result of severe root loss (greater than 50%). Root pruning has become an important arboriculture practice.

Essential root growth is a summation of casual factors:

- The type and quantity of wood formed in a root depends on the growth conditions of the stem.
- The location of the root or root part is dependent on growth of the stem. There is greater growth of roots near the base of trees than on roots further out.
- Carbohydrate (food) storage has priority over growth in roots. Root growth may not occur until a threshold of reserves has been stored in the root. Radial growth of roots begins after "food" reserves have been stored in existing woody roots.
- If there is a depletion of food reserves and a delay in their replenishment, there is a delay in recovery of root growth and a slower growth of shoots.
- Tree stress indirectly affects root growth through the adverse influence on photosynthesis. Stress reduces the amount of carbohydrates available in roots for use and storage.

It is apparent then that condition of the leaves, stems, and roots are all interdependent. Roots have a priority over top growth for the accumulation of food reserves, and that can affect the canopy. A delay in the recovery from root pruning can stress the leaf canopy. If the food-storage reserves in the roots have not been met, root enlargement is delayed. If there is a concentration of roots near the base of the tree, vigor can be retained even though root pruning may be quite close to the trunk, perhaps up to ten feet from the trunk. If carbohydrate reserves are high, chances are enhanced for acceptable recovery and general performance. It makes sense to strengthen carbohydrate reserves before root removal.

Should we thin the top when pruning roots? The purpose is to reduce demands on a damaged root system. Reducing the photosynthetic area reduces the supply of carbohydrates moving to the roots. We all have seen trees survive acceptably well when 50% of the root system has been severed, with little observed reduction in leaf sur-

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face.

The availability of carbohydrates to support new root growth is limited during active shoot growth in the spring. We should avoid root pruning during that time. The worst time to root prune is just prior to bud break. Initiation of cambial activity in roots is a continuation of that in the stem, proceeding from the trunk towards the root tip. Activation of the vascular cambium in the root depends upon the arrival of hormonal substances. One is auxin, much of which is synthesized in the buds, but may also be formed in root tips. It moves downward to the base and outward to the root tips. High concentrations of auxin are necessary for root initiation and it is important in the formation of compression wood in roots. Evidence from Japan suggests that pruning shoot tips stops or delays root growth, an interruption in the supply of auxin. Research from California casts doubt on the advisability of pruning newly planted young trees, probably for this reason. Rapid recovery following the shock of severe root removal is dependent not only on the rapid initiation of new roots, but on the initiation of cambial activity and the movement of auxin from the buds. Top pruning should be limited to removal of weak and shaded leaf surfaces on vigorous trees.

Gibberellin, another naturally occurring plant hormone, stimulates cell elongation. It is produced in roots as well as in leaves and seeds. In roots, it moves through new wood. Rapid elongation of new roots is important to shorten the period of shock after root pruning. Where rapid growth is desired after root removal such as in utility trenching, stimulation through applications of gibberellins may be desirable.

Cytokinins in high concentrations inhibit lateral root formation. Root pruning removes the root tip which contains the highest concentrations of cytokinins and allows callus tissue to close the cut. Thus, root pruning is beneficial to root branching. Nurserymen who root prune and transplant, benefit from this. To the arborist or landscaper who wants rapid branching of roots, high concentrations of cytokinins may be undesirable. Future research will bring more light on how these and perhaps other hormones influence root growth.

Tissue structure is important to root growth. In general, roots are less dense than stems. There is a high percentage of thin-walled paranchyma cells in the large and surface-growing roots. These cells store most of the food, so, removal of large lateral roots can remove large amounts of starch which puts the tree under stress, sometimes escalating to decline and death. The diameter and length of cells in vertical (sinker) and heart roots tend to be smaller than those in lateral roots at a similar distance from the tree-base. These have a high tensile strength which is important when large horizontal roots close to the trunk are cut.

The entire woody cylinder of the root transports water and nutrients, so reduction in root diameter over a long time may not be critical for survival. Some arborists shave large roots on one side to reduce the rates of radial expansion. This appears to work without significantly impairing tree performance, if the shaving is not done too close to the tree trunk.

Long-term soil moisture levels affect the distribution of roots. Some studies suggest that soil moisture has more influence on root distribution than on root size. Under drought conditions, root growth tends to shift towards the root tip rather than to increase in diameter, so severe root pruning in desert areas may be quite harmful. Infrequent irrigation produces poor root growth in surface soils, but more roots in the deeper layers. Growth of deep roots begins later than growth of surface roots. Under droughty conditions, large roots may be deep and may escape pruning. Experience in the West indicates this to be true.

Root growth continues longer at the base of the trunk than further out. Cessation of cambial activity proceeds from root tip to the tree base and thence to the shoot tip. This means that most root activity is near the tree base and for a long part of the growing season.

Temperature effects are also important. There are temperature minimums for root growth which vary with the species. Warm temperatures (68 °F) on shoots can accelerate starch reduction in fibrous roots. At a cooler 50 °F, there can be an increase in soluble sugars in the larger roots. The effects of severe root pruning are probably more drastic in cool-cold climates, especially when soil temperatures are lowering or are below minimum for root growth, due to more food being stored and not used in growth of new roots.

After the roots have been pruned, the regeneration of roots proceeds most rapidly when top growth is least rapid. New root generation, even though rapid, does not require as much energy as is required for shoot growth. In the summer and fall assimilates from the leaves are likely to go to the roots and to the severed ends of roots.

The location of the large roots is arbitrary. They grow where their requirements for air, water, temperature, nutrition, and freedom from toxic substances are satisfied. Tree roots commonly grow outward 1½ to 2 times the height of the tree, yet, arborists consider the risk small if tree roots are cut off at the drip line. If done on one tangential side, about 15% of the roots will be cut. If a single straight-line cut is made midway between the drip line and the trunk, it has been estimated that 30% of the roots will have been severed, and that trees of reasonable vitality should withstand this. In my opinion, adhering to the recommendation of not pruning closer than midway between the drip line and the trunk is, in many situations, more conservative than necessary. It is frequently violated without serious consequences. In California, mature olive trees are transported any time of the year with a 2' X 2' X 1½' root balls and Washington fan palms are transported during the summer with closely cropped roots. I have seen 75% to 80% of the root system of mature southern magnolias in a compacted clay soil destroyed by rototiller, yet resulting in no top thinning. After a short period of severe leaf fall, the trees returned to acceptability in a city government complex. Results of a recent controlled study in Ohio on root pruning of young apple trees indicate that vegetative growth of young apple trees can be reduced by root pruning, but root pruning must be severe and the reduction of growth is only temporary. Growth reductions are likely related to the changed moisture status of the trees. Later reductions in shoot growth, however, can be attributed to an increased allocation of photosynthates to the roots and to hormonal imbalances. Trees re-establish their root-shoot balance by enhancing root growth at the expense of shoot growth. With the development of new roots, water relations in the tree improve and photosynthesis and shoot growth rates increase.

In this apple tree study, water stress was most severe one to six hours after treatment. Leaf wilting was observed for the first seventy-two hours in severe treatments. One day after root pruning, photosynthesis was reduced 35% to 50%. Photosynthesis and transpiration generally followed similar patterns. Both started to recover after ten days. Shoot growth was reduced 25% one month after treatment on the more severe treatments and leaf area was reduced about one-third. Although significant amounts of roots were removed in pruning, no difference in root weight was observed four weeks after treatment. More new roots were produced on root-pruned trees than on trees unpruned. Similar observations have been noted for several other kinds of trees. This illustrates that the effects of severe root loss can be temporary and that root pruning can stimulate production of new roots.

Several years ago, I conducted a test to determine why 65 uniform 3-year-old iron bark eucalyptus trees *(Eucalyptus sideroxylon)* grew vigorously after being severely potbound in one-gallon containers. I trenched 5 feet deep and 18 inches from the trunk on one side. I then directed

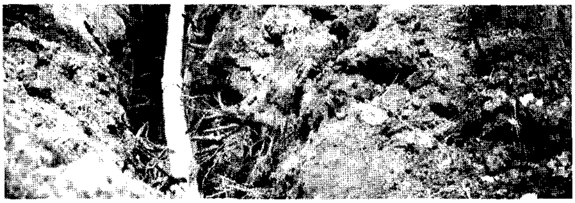

**Fig. 1. Trenching within two feet of this Quercus agrifolia in Berkley, California is risky in this year of drought.**

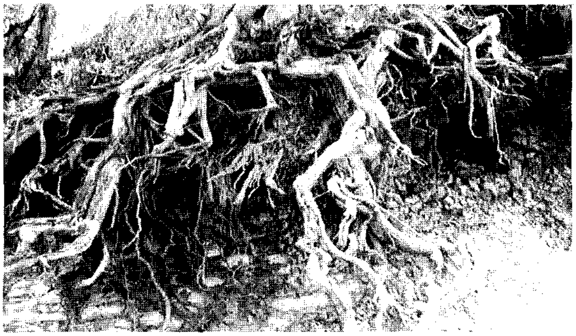

**Fig. 2. A high percentage of the tree's roots are located close to the trunk even though some extend outward several times the tree height.**

a water jet at 200 psi to blast the soil from the roots. Much of the root bark was removed in the process. The trees were left exposed for several weeks, until after the appearance of new-shoot growth. All the trees remained in their original position and most amazing was the rapid growth of new roots and top growth in the weeks following soil replacement.

How can landscape trees survive such a loss of roots? A very high percentage of water-absorbing roots are under and close to the tree stem. I suggest that a high percentage of water-nutrient-absorbing roots are not disturbed. Many, if not most, of the sinker roots originate from the primary roots within four feet of the trunk; these vertically descending roots are minimally disturbed. Downward-growing heart-roots also originate from the buttress of the trunk. So, many trees with adequate vigor and vitality can withstand severe root pruning. Adequate tree vigor and vitality are the key words.

Some arborists use a rule of thumb for transplanting trees which is radical root pruning: a soil ball of 12-inch diameter for each inch of trunk diameter. In practice, this appears fairly realistic for root pruning in the established landscape. When we observe practices in large-tree container-nurseries and the practices of successful tree movers, these figures appear realistic. Trees should not be moved during rapid shoot growth and tree stresses should be alleviated *before* severance.

The effect of root pruning on the stability of the tree is a major factor of concern. This is most important when the tree is very large, very tall, old for the species, has a dense canopy for the root volume (a low root:shoot ratio), or is wounded near the soil line. Unusually strong winds and strong winds from a non-prevailing direction are also important. This excludes small-sized trees, open and naturally grown trees, most trees having adequate vigor and vitality and trees that have been thinned to allow a body of air to blow through. It does not exclude young evergreen trees with a heavy top which are spring-planted and/or stimulated to excessive growth.

In the San Francisco Bay area of California, an informal survey of supervisors responsible for street-tree maintenance indicates that less than 1% of trees fall over as a result of root pruning, planting, being too close to buildings, or being surrounded by pavement. But even that may be unacceptable if substantial damage occurs. City Forester Gary Nauman of Palo Alto recorded the failure of 25 to 50 pink flowering locust *(Robinia* sp.) after root pruning. Gordon Mann in Redwood City cites several storm-damage problems to the following trees which had been root pruned: *Acacia melanoxylon* (black acacia), *Schinus molle* (California pepper), and *Fraxinus velutina* "Modesto" (Modesto ash). Those safe to root prune include: *Cinnamomum camphora* (Camphor tree), *Ulmus americana* (American elm), *Ulmus* pumila (Siberian elm), *Populus* sp. (poplars), *Liquidambar styriciflua* (sweet gum), and *Platanus acerifolia* (London plane). In nearby Burlingame, the problem appears to lie with certain tree species: *Acacia melanoxylon* (black acacia), *Ulmus sp, Juglans nigra* (black walnut), and *Morus alba* (fruitless mulberry) in soft soils. Results from 35 locations surrounding San Francisco Bay with regards to tree failure during severe storms of November-December, 1982, indicated no failure attributed to root pruning, although many trees went down.

Plant Pathologist Terry Tatter, at the University of Massachusetts, says that the probability of tree failure increases with the amount of root system cut. Trees in exposed locations are especially at risk. He advises to remove trees that have lost 50% or more of their root system during construction.

Lee Payne, retired researcher from the Pacific Southwest Forest and Range Experiment Station,

**Fig. 3. The downward growing sinker roots are important to tree survival after root severance.**

in discussing California forest campground trees, says there is an increasingly high probability of tree failure for trees greater than 30 inches in diameter, leaning trees, trees in winds over 30 miles per hour, and in trees with internal rot.

The root system of northern red oaks was studied by Walter H. Lyford, Harvard University. He notes that by the time the trees are 30 to 40 years old and 4 to 5 inches in diameter, the roots can be divided into central and peripheral systems. The central system at the base of the tree extends 3½ to 7 feet and consists of main laterals, numerous vertically and obliquely descending woody and non-woody roots. These provide the support and anchoring system. Although large in diameter at the juncture with the trunk, they taper rapidly to a small diameter of 1 to 2 inches where they lose much of their strength and where they tend to break in storms. Also noted was the fact that sinker roots were found only within 3½ to 7 feet of the trunk.

In his book, *Arboriculture,* Richard Harris says that "if you want to lower the soil grade near the trunk, you will, in many cases, encounter no large horizontal roots or sinker roots until you are within 6 to 10 feet of the trunk. For tree stability, do not cut sinker roots unless they are a considerable distance from the trunk. Horizontal roots can usually be safely cut up to the point where their caliper begins to increase markedly near the trunk".

Severe root pruning of landscape trees does not adversely affect the value of the tree to the general public. Growth reduction and unacceptable appearance from root severance can be of a relatively short duration if the tree has strong vigor and vitality. Trees re-establish their root-shoot balance by enhancing root generation at the expense of shoot growth. With the development of new roots, water imbalances in the tree improve and photosynthesis and shoot growth rates increase.

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