MANAGING URBAN TREE ROOT SYSTEMS

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INTRODUCTION:

Over the past couple of decades, much has been learned about the structure of root systems developed by trees growing in urban soils and environments. The basic principles involved in their development are not complex and can provide insight into how tree management practices can be implemented. The architecture of tree root systems develops in response to the genetics of the tree, the edaphic environment and tree management practices.

Those responsible for tree management should be proactive in the management of root systems rather than attempting to manage tree root problems once they have developed. Trees which have the space to develop undisturbed root systems tend to grow well and mature into sound, low-maintenance specimens. It is essential that in designing urban landscapes appropriate space is allowed for proper root development, in a way that minimizes subsequent root system interference and enhances tree vigour and health. Such trees have a higher capacity to cope with pests and diseases, and as a consequence they require lower levels of maintenance and arboricultural care. Their establishment and maintenance costs are significantly lower.

ROOT ARCHITECTURE AND MORPHOLOGY:

When a tree seed germinates in undisturbed natural soils, the radicle emerges and usually develops into a tap root. In Australian native species, such as *Eucalyptus* and *Acacia,* it is not uncommon to find a seedling of 20mm height with a primary root of 150-200mm in length. This root then develops as a tap root, securely anchoring the young tree and providing necessary water and nutrients to facilitate seedling growth. It also provides the basic framework from which lateral roots develop.

In most trees species, however, the tap root should be considered a juvenile characteristic, which persists for the early establishment phase of the tree's life cycle. The tap root which often descends almost vertically soon reaches soils that are compacted, and low in oxygen and nutrients. Furthermore, the nutrients in the rhizosphere surrounding the tap root are soon exhausted. Oxygen levels in soils decrease rapidly with depth, which explains why 95 % of the absorbing roots are so close to the surface and why tap roots die back. The root has then served its purpose and dies back leaving the spreading lateral roots to perform the roles of absorbing nutrients and water and of anchoring the tree.

The root system of mature trees then tends to be spreading and relatively shallow (Figure 1). The typical tree system consists of a shallow spreading root plate, as opposed to a rootball. This root plate of lateral spreading roots is complemented by the presence of descending (or vertical or sinker) roots, which tend to occur around the base of the tree or close to the trunk (Figure 2), where oxygen is more readily available and where nutrients and organic matter are being actively recycled (Coile, 1937; Perry, 1982). Descending roots tend to be concentrated around the base of the trunk where they are often confused for tap roots, but they are morphologically and anatomically distinct from tap roots. While the lateral roots are often within 200-300mm of the soil surface, descending roots may grow to depths of 1000mm or more. They persist for a number of years and at maturity may be 100-150mm in diameter. There are also descending roots further out along the root plate, which tend to be smaller in diameter and shallower in their descent. These roots may persist for a number of years before they die back and are replaced (Moore, 1995; Smith and Moore, 1997).

Figure 1. The spread and depth of a typical tree root system (from Watson and Neely, 1994).

Most large trees have 95% of their roots growing near the soil surface, with the majority of their small absorbing roots concentrated in the surface 150-200 mm of soil. A tree grown in the open typically has a horizontal root spread 2-4 times the radius of the crown and has most (>60%) roots outside of the canopy dripline (Gilman, 1988; Harris, 1992; Harris and Bassuk, 1993; Perry, 1982). In disturbed sites where the root systems have been interfered with, or where there is paving the extent of root spread may be even greater, with frequent observations of root spread 5-6 times the radius of the crown.

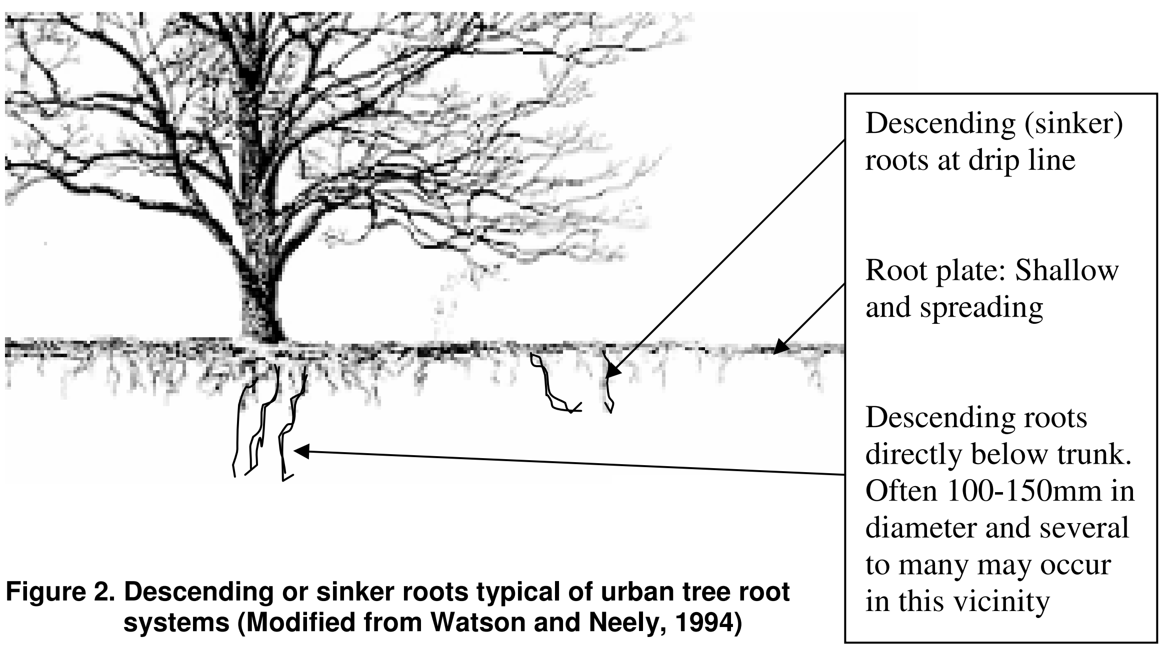

Figure 2. Descending or sinker roots typical of urban tree root systems (Modified from Watson and Neely, 1994)

Root growth is essentially opportunistic in its timing and orientation (Smith and Moore, 1997). Because root tips are forced through the soil particles as the root elongates, the penetrative resistance of the soil affects root growth and development. Root growth tends to follow lines of least resistance. In the urban landscape these are usually disturbed soil areas created by trenching, service provision and the creation of hand structures in the landscape (Yau, 1991; Moore, 1994). Roots tend to move along disturbed and fractured soil profiles, proliferating wherever the environment provides the water, oxygen, minerals, support and warmth necessary for growth (Perry, 1982). They grow along concentration gradients of oxygen, nutrients and moisture and then proliferate where resources are available (Perry, 1982)

This aspect of tree root growth needs to be managed if trees and hard structures are to co-exist in urban landscapes. Proper back filling of trenches and around foundations and footings is a practical and sensible approach to managing the presence of trees (Moore, 1994). Management techniques that re-establish appropriate soil profiles should be employed to minimize the risks of root invasion along fractured profiles which might subsequently see root proliferation in the region of underground services or the foundations of hard structures.

The importance of the relationship between the canopy of urban trees and the root systems which support them cannot be over-estimated. When *Eucalyptus obliqua* seedlings were decapitated root tip growth ceased within 24 hours and prior to the development of epicormic or lignotuberous buds, which marked the beginning of the recovery phase for these seedlings, root tip growth had to recommence. In most cases, root tip growth commenced 24 - 48 hours before the buds began to develop (Moore, 1982).

In other trials, trees were subjected to various levels of defoliation, decapitation and sub-lethal stress. The treated plants showed considerably reduced root growth immediately after the treatments, but root tip growth commenced just prior to foliage and stem recovery. In the recovery period of 20 weeks, carbohydrate was preferentially allocated to the foliage and stems (figure 3). At the end of the 10 week period, there were no significant differences between the treated and controlled plants in root or shoot fresh weights, seedling heights or leaf numbers. After 10 weeks, both control and treated plants showed similar patterns of growth (Moore, 1982).

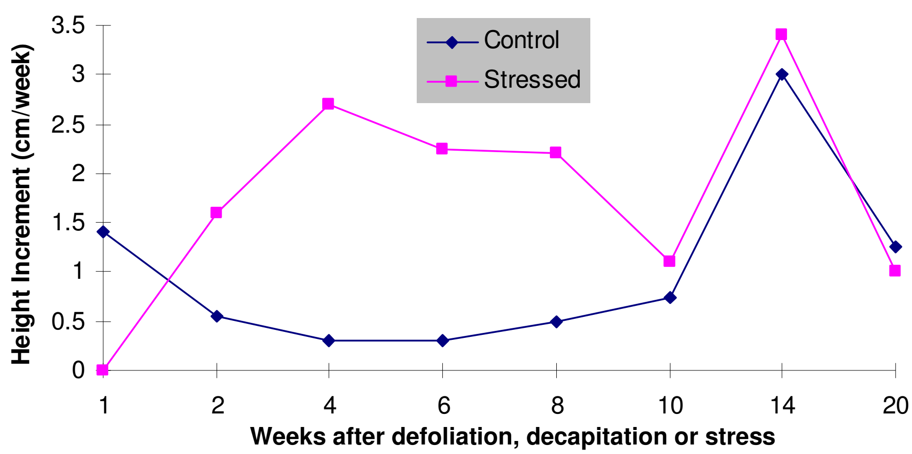

Figure 3. Height of *E obliqua* seedlings for twenty weeks after defoliation, decapitation or stress (Moore, 2001).

The fine absorbing tree roots are shed regularly. In many species there is a turn over of such fine roots on an annual or seasonal basis, much like the shedding and replacement of leaves. Such rapid replacement is essential if the trees are to maintain healthy absorptive surfaces for the uptake of water and nutrients. This pattern of root replacement affords some interesting opportunities for tree root system management.

It should be remembered that for trees that are grown through nursery propagation systems, root systems will not have a natural tap root development. Cutting grown specimens will not have a tap root as lateral roots develop from the callus at the base of the cutting. Furthermore, specimens that are cutting or seedling grown, and which are pricked-out and potted-on will have a lateral root system from a very young age as the tap root is removed as part of the production process. Such root systems are not necessarily inferior to those that develop in the more natural pattern of a tap root, but merely different. They may require a different management regime, however, in the early stages of tree establishment.

MANAGEMENT IMPLICATIONS OF TREE ROOT ARCHITECTURE:

In urban environments it is often a matter of managing to ensure that there is good root growth where you want roots and little or no root growth where you do not want roots. Managing soil conditions to achieve these apparently simple objectives is about manipulating the edaphic factors affecting root growth (Table 1). These conditions also need to provide conditions that are conducive to the development of the soil biota, and particularly the mycorrhizal suite of species that is essential for healthy tree growth.

Large urban trees growing in situations where their root systems are not subject to interference from compaction, trenching, service installation or other construction activities have been found to have long life spans. Despite their advanced age and large structures they also have fewer maintenance requirements and lower management costs (Moore, 2004). These specimens tend to have fewer structural defects, and because of there better health and vigour cope effectively with environmental stresses and pests and disease attack (Graham and Ferrrier, 1997; Andrews Harris and Skipper, 2000; Curnow, 2003). These large specimens planted in large beds with adequate above and below ground space are also less prone to wind throw during major rain, wind and storm events (Moore, 2008).

Trees planted in large, mulched beds where their roots and canopies can develop and remain intact are the best and most long lived urban specimens. The best urban trees are those which have been interfered with least and have been free from past poor arboricultural practices. Even modern arboricultural practices, apart from formative pruning, should be kept to a minimum whenever possible to enhance the aesthetic and functional life spans of urban trees.

Table 1, Management Strategies for the Manipulation of Root Growth

	Oxygen	**Water**	**Nutrients**	**Organic Matter**	**Penetrative Resistance**
Encourage Root Growth	High	Appropriate	Appropriate	High	Low
Limit Root Growth	Low	Low or very high	Low or very high	Low	High
Management Strategy to Encourage Root Growth	Mulch, aerate and de-compact	Mulch and sub-surface irrigation	Appropriate use of fertilizers, mulch and compost	Mulch and compost	De-compact and mulch
Management Strategy to Eliminate or Minimize Root Growth	Compact soil, use of hard surfaces	Keep soil very dry by drainage or hard surfaces	Use of hard surfaces and elimination of compost and mulch	Remove mulch, scrape, hard surfaces	Compact soil

In urban landscapes the focus of tree root management is often placed upon the spreading, absorbing lateral root system. Such a focus is both understandable and sensible as these roots provide water and nutrition to the tree. However, it is important to recognize that the descending roots are an important part of the stabilizing system that anchors the tree. Should the descending roots die off due to poor aeration as a result of compaction, or because of rises in the water table, then the stability and future survival of the tree can be put at risk. The loss of descending roots as a result of water-logging is also quite common and can leave affected trees prone to wind throw.

TREE ROOT SYSTEMS AS ASSETS:

Given the importance of root systems to the establishment and survival of urban trees, they must be seen and managed as valuable assets. While the value and importance of root systems to the vigour, condition and life span of trees has often been emphasized, it is rare that root systems are subjected to an asset management regime.

Trees which develop canopy structural problems such as multiple co-dominant stems or crossovers are often rightly targeted for removal. Removal also often involves stump and root removal. However, if the trees are young and vigorous and have healthy root systems and the capacity for suckering and or lignotubers (basal burls) from which regeneration can occur, then the developed root systems and lignotubers should be seen as assets. Often healthy and vigorous trees can be established more rapidly from suckers (where appropriate) or from lignotuberous shoots in a fraction of the time, and with a fraction of the resources that it would take to establish the same species of tree from seedlings.

Established root systems allow very rapid above ground plant growth and establishment (Table 2). Not only do large and established root systems provide greater quantities of water and nutrients to the growing shoots, but there is an often a significant reserve of carbohydrate stored in the root system. This reserve can be directed to the re-establishment of a canopy and branching structure, or provide much needed energy to cope with pest or disease attack. At a time of ongoing chronic drought an established root system also gives access to a greater volume of soil from which water can be extracted. This can also provide the developing sucker or lignotuberous shoot with a significant survival advantage over a young seedling in many urban environments. Re-establishment for regrowth will out-compete a seedling of the same species in most situations.

Table 2. Growth of Seedlings compared to lignotuberous re-growth in *Eucalyptus obliqua* (Moore 1982).

	Species	Seedling	Lignotuberous Growth
Ave weekly growth rate (mm)	E obliqua	3.0	28.0
Maximum weekly growth (cm)	E obliqua	3.2	27.0
Maximum Annual Growth (m)	E obliqua	1.75	6.20
Eucalyptus obliqua seedlings for data in rows 1 and 2 were glasshouse grown under ideal conditions, and *E obliqua* for data in row 3 were field grown at Emerald, Victoria.			

Much has been written (Watson and Neely, 1995; Neely and Watson, 1995) on the protection of trees during site development works. Whilst damage to the trunk and canopy is still common, there is no excuse for it. Protection for these parts of the tree is logical and for the most part based on common sense. It does not require an in-depth knowledge of trees to protect the trunk from mechanical damage, and the foliage from mechanical impact or accidental chemical application. In this era there can be no excuse for such transgressions.

Damage to root systems however, is still commonplace and requires a more sophisticated approach. Most arborists and horticulturists well understand that a healthy and vigorous root system is the key to healthy and vigorous tree growth. The concept of a tree protection zone (TPZ) for protection of the trunk and root system during site development and construction works is well understood. However, while many approach the imposition of a TPZ on the basis of the application of simple and uniform formulae, it must be understood that these are a guide only.

Each tree develops its own unique root system in response to its genetics, its interaction with the environment, and management practices. While the TPZ is a huge improvement over no tree and root system protection, a formulaic approach which generalizes cannot protect all trees adequately, nor can it provide adequate protection in every situation. Management is only as good as the information that informs relevant decisions. To properly locate root systems will require data on the aspects of root architecture, such as where the major (>50mm diameter) roots are located and their spread, density and depth. Such data can only be acquired by sampling and measuring root systems on site.

Qualified arborists have the necessary skills and knowledge to undertake such data acquisition. Until recently the collection of data may have involved taking core samples using a soil auger on a grid system and identifying root presence, or techniques such as exposing roots with an air knife. These are non-destructive of the roots if done properly but are time-consuming and have a significant impact on the site. The proper use of new technologies, such as Ground Penetrating Radar (GPR), may also be both accurate and cost effective in identifying the major components of tree root systems, and allow effective tree root protection during construction and site development (Ryder, 2006). The use of TPZ for site management of mature urban tree specimens is only part of a protection strategy which must be finalized by collecting data on the root system itself, and basing decisions on real rather than assumed knowledge of the individual tree's root system.

CONCLUSION:

Tree root systems are the key to successful urban tree growth and establishment. By providing adequate space above and below ground for tree growth, interference with tree root systems and canopies can be minimized, which enhances plant health, vigour and longevity. Knowledge of root system architecture and morphology is essential if urban trees are to be managed efficiently and cost effectively as major community assets of significant value.

Large and established root systems and lignotubers should be considered as assets in their own right. Stump grinding and root removal are often done too hastily without consideration of the value of regrowth, and its capacity to provide tree replacement in a fraction of the time taken to establish urban trees from seedling growth. Proper management of urban trees requires a holistic approach that is based on an informed knowledge of the tree's root system that is based on the collection of data specific to the tree and the environment within which it is growing.

Urban trees are valuable community assets, whose value is likely to increase as the real economic value of their functions within cities become better and more widely known under the umbrella of global warming and climate change. High calibre management of these vital urban assets must be based on sound decision making processes that utilize specimen specific data to ascertain root architecture. These data can then be used in conjunction with TPZs to better inform the management and protection of urban trees during construction and site development. They can also contribute to the efficient, and surely now inevitable, under-grounding of services. It is a significant period in urban tree management and the stakes are high. Making professional and well-informed decisions about urban trees now will guarantee an impressive legacy of urban trees and landscapes for future generation of Australians. Failure sees a diminished legacy where even the legacy of parks, gardens and streetscapes of previous generations is put at risk.

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