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TREE ROOT NETWORKS : A VITAL INGREDIENT OF TREENET

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INTRODUCTION

The knowledge of the tree below the ground has expanded dramatically over the past two decades (Perry, 1982; Yau, 1991; Moore, 1995;Watson and Neely, 1994). The era in which those managing urban landscapes could ignore the management of tree root systems, because they were "out of sight and out of mind", has long passed. So too should the era when people assumed that large trees in urban sites had large tap roots, and that root systems could not be managed to meet the demands placed upon trees.

In most urban situations, trees are planted into disturbed soil profiles, which have been substantially altered by past human activity (Smith and Moore, 1997). Such profiles need to be identified (Table 1) and appropriate management strategies implemented if trees are to establish and survive at acceptable rates in such environments. This may require a re-evaluation of the approach to the specification of the planting hole (Figure 1), and communication with urban planners, landscape designers and architects that will provide better information than that which has been traditionally available.

	TYPE	DESCRIPTION
1	SCALPIC	Cut land surfaces in which natural topographic contours are broken and 'rock structure' occurs near the surface.
2	GARBIC	Organic solid waste and or a large concentration of methane occurs in the soil atmosphere to within 1 to 2 m of the soil surface, for example a sanitary land fill.
3	URBIC	Miscellaneous urban fill with manufactured inorganic artefacts (for example bricks, glass and concrete) in the upper profile.
4	SPOLIC	Locally derived moved earthy soil material, but without artefacts.
5	DREDGIC	Soils containing dredged materials.

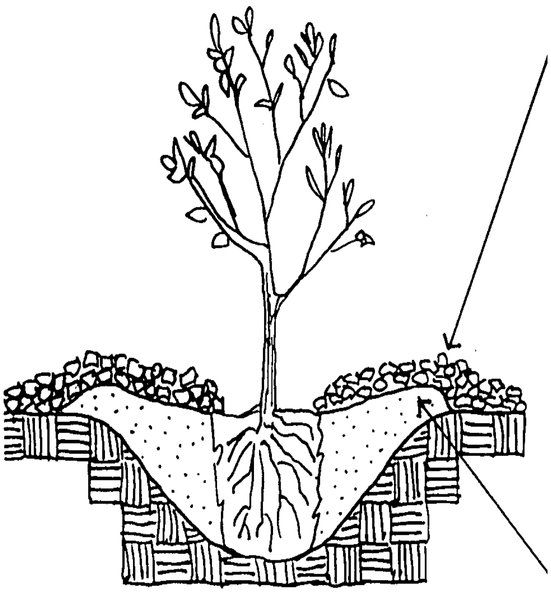
Table 1. A classification of soil types commonly found in urban environments from Smith, 1997.

ROOT SYSTEM MORPHOLOGY

Large trees usually have large root systems to support them. While this may seem axiomatic to horticulturists, its importance is all too rarely appreciated by those from other professions responsible for interacting with tree management in urban sites. Rarely are the issues of adequate soil root volume, or an appropriate area of open surface to the atmosphere necessary for successful tree establishment and growth given attention by such professionals. Even the space around trees planted in streets and the sizes of grids used around them often seem to have been arbitrarily derived.

The network of roots in the root plate is made up of a framework of roots. The largest are the primary or first order roots, which branch to the secondary or second order roots, these to the tertiary or third order, and so on to the finest of absorbing roots. Fine roots are regularly shed and replaced, in a way that is similar to leaf shedding. Roots become woody and compartmentalise as they age, and it would appear that there are many systems of protection and defence against pests and diseases that are analogous to those that are now understood to exist in the trunk and canopy.

Figure 1. Recommended design for a typical uncovered individual tree pit or planting hole. The tree could be small container grown stock, semi-advanced or advanced material. Adapted from Craul (1991). And drawn by K.D. Smith for Smith and Moore (1997). Not to scale.



However, it is well known that tree root systems tend to be shallow and spreading , rather than restricted and deep (Watson and Neely, 1994; Moore, 1995). Given this knowledge, urban landscapes should be appropriately designed to accommodate this basic biological need. The idea that trees can be planted in deep narrow holes and perform in an acceptable fashion over the usual life expectancy period is unreasonable. What is required is some lateral thinking which sees the space provided as extensive and shallow, and which incorporates the provision of necessary utility services under the trees. Such an approach should see the demands of both the hard and the soft landscape successfully managed.

In recent years the rootball concept, which saw the root mass as relatively narrow and deep has been replaced with the notion that the spreading root system forms a wide but relatively shallow root plate. This concept has been very useful, especially in educating other professionals about the importance of tree root systems in urban situations that involve interaction with the hard landscape. It has also been useful in negotiating with design professionals, planners and other decision makers to provide trees with some of the essential biological requirements mentioned above.

The focus on the root plate, however, has tended to distract people from recognising the importance of the descending roots. These roots, sometimes called sinkers or vertical roots, are an important component of the overall root system morphology. In trees that fall, the root plate is often intact, but the descending roots, which appear to anchor the root plate, are usually damaged or in some cases missing (Moore, 1995). The focus on descending roots does not mean that the root plate is not important, but rather emphasises that it is the whole root system that is important to tree survival and growth.

The shallow spreading roots that make up the root plate must be properly managed, but so too must the descending roots. These descending roots are easily damaged or destroyed by changes that see rises in the watertable, changes in soil aeration or nutrition or disruption to subterranean water flows. These changes commonly occur when existing trees are impacted upon by construction works, and the creation of substantial foundations for hard landscape. It is also possible that paving over the root systems of pre -existing trees can also cause loss of descending roots. An investigation of the root systems of fifty mature trees of various species that had fallen during strong wind storms, revealed that none had intact descending root systems, and that none had any root material that was still living below a depth of 0.5 metres, and often less (Moore, 1988). In each case the trees appeared healthy and the root plate remained intact, but there was evidence that descending roots had been either damaged or had died. In some instances, rises in water tables due to construction work seemed to cause descending root decline.

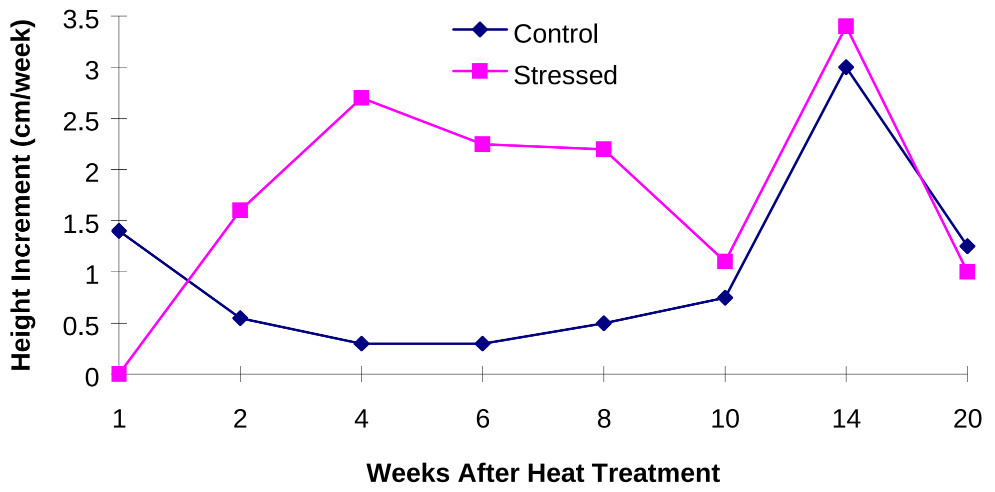
THE ROOT:SHOOT INTERACTION

The closeness of the relationship between the canopy of trees and the root system, which supports them cannot be over emphasised. It is well understood that to get a healthy vigorous tree requires a healthy supporting root system. However, what is often not recognised is the intimate relationship between root growth and canopy. For example the defoliation of young *Eucalyptus obliqua* seedlings saw root tip growth cease within twenty-four hours (Moore, 1982). Root tip growth was observed to commence between 24 and 48 hours before epicormic or lignotuberous buds of seedlings began to shoot.

Even more spectacular is the relationship between root and shoot growth in the recovery phase after stress (Figure 2). Clearly the relationship between root growth and successful plant establishment and canopy development is intimate, and in the young seedlings tested, there would appear to be a natural root:shoot ratio, which relates canopy biomass to root biomass (Moore, 1982). Other studies have shown that such relationships are not simple, and that simple rules and ratios for all species do not apply. However, the concept is well worth further research.

Recognising the close relationship between good root biology and successful tree establishment, requires appropriate management of the environment in which roots grow. In most urban situations it should be assumed that the trees will be growing under stress for at least part of the year. The stress may result from high or low levels of water, low soil oxygen or low or high soil nutrient status. In such a situation an understanding of stress biology is important to successful tree management. Trees display various levels of stress resistance to a range of environmental stresses, but the resistance may be due either to stress tolerance or stress avoidance mechanisms. It is important to know which is which when a tree is recognised as having a high level of stress resistance.

Figure 2. **Height increment of *Eucalypts obliqua* seedlings for twenty weeks after a period of stress. The stress imposed was to heat the seedlings at 60°C for a period of eight minutes, which is a sub-lethal level of stress. After ten weeks control and stressed seedlings were indistinguishable from each other (after Moore, 1982).**



The use of *Eucalyptus* species in urban plantings is increasing rapidly in Australia. Some species have been identified as being suitable for urban use on the basis of their stress resistance, and in particular their capacity to cope with drought. However, species like the River Red Gum (*E camaldulensis)*, which is the most widely distributed eucalypt in Australia, and which occurs in many arid parts of the continent are drought avoiders. This species only grows in places where water supply is constant, or where the extensive root system can tap into subterranean water sources. It has little capacity for stomatal control and so is rarely suitable for restricted and dry urban sites. Despite this biology, it is still often recommended for urban planting, especially by landscape architects attracted to its form and spreading canopy. It would be more sensible to seek plants, which avoid drought through high levels of stomatal control, or which can tolerate drought through the capacity to sustain their metabolic activity in the face of lowered internal water potential. These plants should offer much better prospects for use in urban landscapes.

TREES AND SOILS: A NECESSARY INTERACTION

Tree roots tend to grow along lines of least resistance (Yau, 1991). As root tips grow and subsequently elongate, they do not grow around soil particles as many people think. Rather the tip is forced through the soil and is constantly abraded by the soil particles. In soils with high bulk density (Smith, 1997), the resistance to root tip growth, elongation and subsequent development is high. In such soils the establishment of an extensive root system can be limited and so it may take many years before the plant can successfully establish and grow in such a soil.

In other situations however, where the natural soil profile has been shattered by earth works for the construction of foundations, pipelines or other hard structures, the soil bulk density is much reduced and so the roots can extend and develop along these lines of lesser resistance. In such situations the construction processes often provide ideal conditions for root proliferation in the very places that landscape managers would wish to have few, if any, roots at all. In short bad management and poor arboricultural practices are inadvertently providing conditions of low soil penetrative resistance, high soil oxygen levels and enhanced soil water levels in places where root growth is not wanted. If organic matter is added to this list by inappropriate back filling in such situations almost ideal root growth conditions have been provided. It is obvious that such a situation must be properly managed.

The issue of properly managing soils around hard landscape constructions is an issue that should be addressed with some urgency (Moore, 1994; Watson, and Neely, 1995). Too often engineering and landscape specifications are inadequate in protecting hard structures from damage due to the presence of large trees. Many of the management practices required to avoid these situations are simple but rarely practiced (Table 2). It is important that the soil profile around footings, foundations and paving, and along trench lines should be reconstructed by proper back filling, and perhaps heavy compaction. Such an approach should minimise the risks of root proliferation in places where root growth is undesirable.

Table 2. Simple management practices for limiting root damage to hard structures and services (after Moore, 1994).

* PROPER INSTALLATION OF PLUMBING, GAS, COMMUNICATION AND ELECTRICAL SERVICES

* PROPER BACKFILLING OF TRENCHES AND FOUNDATIONS THAT RECONSTITUTES THE SOIL PROFILE

* APPRECIATE THE VALUE OF COMPACTION AS A ROOT MANAGEMENT TOOL

* MANIPULATE ROOTS BY THE MANAGEMENT OF SOIL:
    - OXYGEN
    - WATER
    - NUTRITION
    - PENETRATIVE RESISTANCE

* ESTABLISH THE MANAGEMENT OF ROOT STRUCTURE AND DEVELOPMENT AS PART OF SITE MANAGEMENT ROUTINE

* DEVELOP APPROPRIATE SPECIFICATIONS FOR HARD STRUCTURES, WHICH RECOGNISE THE PRESENCE OF TREES, AND WHICH WOULD INCLUDE:
    - PAVING
    - FOUNDATIONS
    - SERVICES

MANAGING TREE ROOT SYSTEMS

Compaction

For most arborists compaction is regarded as a problem that has to be dealt with to improve the quality of trees growing in sub-optimal urban sites. However, compaction can be a useful tool in the management of trees in urban sites. In understanding that trees require good levels of oxygen, moisture, nutrients, and low levels of soil penetrative resistance for healthy root establishment and growth, these can be inverted and used as management tools to discourage tree root development in undesirable places. A competent arborist with a good knowledge of tree root biology should be able to restrict root growth by creating conditions which reduce oxygen, moisture and nutrient levels and increase penetrative resistance. The easiest way of achieving these aims is to heavily compact the soil and to direct moisture and irrigation away from such sites.

This approach to tree root management has some significant implications for management practices in disturbed landscapes and construction sites. Arborists and horticulturists should always be involved in the planning and decision making processes on such sites to ensure that practices which recognise the needs of tree roots systems are implemented. Some of these practices (Table 2) include the use of compaction in back filling around the foundations of hard structures and the proper back filling of service trenches. By doing so root growth in such places will be discouraged, especially if organic matter and moisture is also restricted. On the other hand, every effort should be made to ensure that where tree roots are to establish conditions of appropriate levels of soil aeration, moisture, nutrients and bulk density are provided. In this way, arborists can effectively manage the development and structures of the root systems which trees develop.

Soil Oxygen, Nutrition and Moisture Management

Given that it is possible to manipulate the growth of root systems by altering moisture, oxygen, nutrient or soil density levels, it is important that this approach should be used, and indeed some landscape managers have been managing root systems using some elements of this approach for decades. It has been clear that different irrigation regimes can result in the development of quite different root systems on the same species of tree. Infrequent watering can result in a root system that is sparse and spreading and which exploits a large volume of soil to meet the trees needs, (Fernandez, Moreno, Cabrena, Arrue and Martin-Aranda, 1991). Frequent watering can produce a shallow dense root system that occupies a much smaller volume of soil. It is not a matter of one root system being better than the other, but getting the sort of root system that is intended and for which the environment is managed (Moore, 1991).

If a tree is to be planted in a remote place where irrigation is unavailable and where subsequent management is to be at a low level it is much better that it develop the sparse and spreading root system. If however, the tree is growing in an urbanised area where soil space is limited, then it is better that a shallow dense root system develops. Trees planted along roadsides or in shopping precincts, should have dense shallow root systems and so intensive irrigation systems should be installed as a matter of course. By doing so the risks of disruption to hard structures can be significantly reduced. The tree will remain safe and healthy provided that the canopy is managed appropriately, bearing in mind that the root system will be unable to support a large canopy that offers a substantial resistance to the wind.

There are many situations where proper tree root management, using relatively simple techniques, can reduce damage to hard structures and prolong the useful amenity life of an urban tree. In many Australian cities as trees age and become larger, there are serious concerns that tree roots may do serious damage to house foundations, especially if the soil types involved are reactive clays. One of the simplest solutions is to install a low cost irrigation system, which not only keeps the soil moisture content uniform, which reduces the effect of expansion and shrinkage of reactive clays, but can also be used to manage the development of shallow and dense root systems. Such root systems are less likely to cause damage to dwellings. By imposing an appropriate irrigation regime sophisticated root management practices can be imposed.

CONCLUSION

Trees planted in urban sites are usually growing under conditions that are sub-optimal and as a consequence they require appropriate, and sophisticated management if they are to establish and achieve their full potential as amenity trees. It is important that both climatic and edaphic factors are considered as part of these management factors, and that the basic biological requirements of trees below the ground are considered by those responsible for planning and managing created landscapes.

Considerable advances have been made over the past two decades in the understanding of tree root biology and the arboricultural practices and technologies used to manage trees in urban landscapes. However, some of these advances are being threatened by political and other decision making processes, which exclude or minimise horticultural input. Too often aspects of the hard landscape are given priority over the vegetation components and this puts landscapes at considerable risk.

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