Urban Soil Science – Principles & Practices
Urban Soil Science

Principles and Practices related to the Planting and Care of Trees.

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Abstract

Firstly, an overview of the important chemical and physical relationships in soils that are relevant to the growth of trees particularly in the urban environment are presented. It is necessary to know certain chemical and physical principles so that the solutions presented in the second part can be understood and site specific solutions can be developed.

Part I Principles of Urban Tree Soil

1. Soil Chemistry and Physics

The following discussion is a very simplified revision of basic soil chemical and physical properties which are important to appreciate before decisions can be made about the correction of soil properties. It should allow the technician to have a basic understanding of soil test results and why certain recommendations are made.

Chemistry

pH

The acid/alkali balance is very important in maintaining optimum availability of applied nutrients. At very acid pHs soluble aluminium can become toxic, phosphate is unavailable, and calcium levels can be low. At high pHs iron and other trace elements are rendered unavailable because they are locked up as hydroxides and carbonates. Thus the preferred pH range for optimal growth of most plants is between 5.5 and 6.5 in calcium chloride.

Some plants, for example trees of the Ironbark species, appear to be extremely acid tolerant. Others, such as Casuarina littoralis appear to be incredibly tolerant of both severely acidic soils (acid sulphate soils) and highly alkaline soils. This does not, however, mean that these plants prefer extreme pHs, simply that they can tolerate it where others cannot. The soluble aluminium or unavailability of trace elements still stresses them and reduces their overall vigour.

Where pH adjustment is difficult or impossible there are several guides available to aid plant selection for tolerance of the conditions found. We commonly use “Grow What Where” (Australian Plant Study Group 1984) as a guide but it should be recalled that much of this information is anecdotal and not based on individual plant research.
Salinity and Cation Exchange Properties

Salinity and Cation Exchange are interrelated in that soluble salts can be present in true solution in the soil water, or held by the cation exchange properties of the soil. The Cation Exchange Capacity (CEC) of a soil is a negative charge existing on soil particles which tends to hold the positive charged cations against leaching. The common cations are sodium, potassium, calcium, magnesium, ammonium and aluminium. The phenomenon is called cation exchange because it is possible to displace or exchange one cation for another. For example, excessive use of ammonium fertiliser can displace calcium leading to poor pH buffering and soil acidification. Organic matter and most clays have a high CEC, whereas in sands it is low. Thus CEC usually peaks in the biolayer due to organic matter, or the top of the B horizon where clay content is maximal.

There are many ways to express the amounts of the major cations on the exchange capacity. Some laboratories use parts per million (ppm or mg/kg), some give milliequivalents/100g of soil. The correct way to express the ratios of cations present is to say what proportion of the CEC is filled with each cation, that is, to convert the meq/100g to a percentage of the CEC. Thus, results are most easily understood if expressed as in Table 1.

Table 1. Normal Ranges for Exchangeable Cations

<table>
<thead>
<tr>
<th>Cation</th>
<th>Ideal Range % of CEC</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium</td>
<td>&lt; 5</td>
<td>Sodium causes poor structure</td>
</tr>
<tr>
<td>Potassium</td>
<td>5-10</td>
<td>Lower amounts in heavy clays</td>
</tr>
<tr>
<td>Calcium</td>
<td>60-75</td>
<td>Calcium must be 3-6 times the Mg level</td>
</tr>
<tr>
<td>Magnesium</td>
<td>15-25</td>
<td>Important in chlorophyll production</td>
</tr>
<tr>
<td>Aluminium</td>
<td>&lt;2</td>
<td>Toxic element in larger amounts</td>
</tr>
</tbody>
</table>

These ratios are not just important chemically, excessive sodium and inadequate calcium will cause a condition called sodicity or sodic soil. This causes an alkaline pH, clay dispersion and poor physical properties (crusting, erosion, poor gaseous exchange). It is corrected by bringing the calcium level up to its proper 60% of the CEC with either lime or gypsum depending on pH.

Where excess soluble salts are present either historically or through some addition mechanism such as poor quality water, osmotic stress is placed on the roots reducing their ability to absorb water and ultimately, if levels are high enough, wilting, burning and death can result. Salinity is estimated by measuring the electrical conductivity of a soil water extract. Tables of salinity tolerance of some trees are available in Hitchmough (1994) and Handreck and Black (1994).

Salinity is not usually a problem in well drained soils in humid zones and is often present only at depth even in arid soils. A change to the moisture fluxes ie reduced surface infiltration combined with increased surface evaporation or inappropriate irrigation scheduling can lead to a rise in salts up the profile. Thus salinity under
pavements in outback towns is an issue because the pavement eliminates downward leaching but some surface evaporation still occurs drawing salts upward.

Artificial leaching with irrigation water is the normal salt remediation process but selection of plant material is sometimes the only choice if this is not possible. Australian Plant Study Group (1980) provides a range of salt tolerant native species, Hitchmough 1994 provides a reasonable list of exotic and native species tolerant of various salinity ranges.

**Phosphorus**

This important element is subjected to a lot of misunderstanding due to the commonly held view that Australian soils are all low in P. While this may be true for most unimproved soils, in urban soil we often find excessive amounts due to an overemphasis on P in maintenance feed programs and to the general pollution associated with human society. We use the data in Table 2 to interpret result on a Bray (acid fluoride) extract.

<table>
<thead>
<tr>
<th>mg/kg of P</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-5</td>
</tr>
<tr>
<td>5-10</td>
</tr>
<tr>
<td>10-20</td>
</tr>
<tr>
<td>20-40</td>
</tr>
<tr>
<td>40-80</td>
</tr>
<tr>
<td>&gt; 80</td>
</tr>
</tbody>
</table>

Table 2. Guide to Phosphate sufficiency Bray No 1 extract.

For most greens and intensive turf P levels around 30mg/kg are usually more than adequate, any amounts over this and insoluble phosphates can cause trace element problems. The P level can change rapidly in sandy soil but in heavy soils it may take years to see apparent changes.

Producing a test result of the correct format is only one part of the story. Generally the correction of problems and the production of recommendations on rates and special fertiliser mixes will require the services of a skilled agronomist/soil adviser. As a guide to the art of proper pH correction we use Table 3.

While all these ameliorants are better worked in to the soil, this is not possible in an existing turf and surface additions must be used. These are effective but to incorporate liming agents to greater depth they can be mixed with coring sand and use during a coring or hollow tyne operation. The formulation of rates and methods of addition depend on many factors and the services of a qualified turf consultant is usually required. Table 3 gives no information of the rates required.

**Table 3. pH and Ca/Mg ratio adjustment.**

<table>
<thead>
<tr>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acidic</td>
</tr>
</tbody>
</table>

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Once these basic properties of pH, Ca/Mg ratio and exchangeable cations have been properly balanced good responses to a normal feeding program should be seen. However there are many situations (e.g., alkaline sand) where continued monitoring and development of fertiliser programs will require skilled advisory help to give the best and most trouble-free performance.

### Oxygen and Redox Potential.

A well aerated soil shows soil gas levels close to those of the free atmosphere i.e., 21% oxygen and 0.03% carbon dioxide. Two factors are required to cause depletion of oxygen and build up in carbon dioxide to the detriment of root growth. Firstly, there must be something in the soil demanding oxygen such as a respiring root or respiring micro-organisms feeding on buried organic matter, and secondly there must be some kind of restriction of gaseous diffusion through the soil. Restriction in gaseous diffusion occurs through low pore space as a result of compaction or poor soil structure, or because of distance from a free atmospheric surface.

The degree of anaerobic conditions can be measured on a scale similar to the pH scale. This is the pE or redox potential (reduction/oxidation potential). At high redox potentials things are said to oxidising, at low redox potentials they are reducing or anaerobic. There are degrees of redox potential and as redox drops various chemical reactions occur in sequence, first nitrogen then manganese, iron, sulphate and lastly organic matter is reduced to give the toxic by-products nitrite, manganous ions, sulphide and in the worst conditions methane.

Anaerobic conditions can be seen and smelled due to the presence of black iron sulphide, and rotten egg gas (hydrogen sulphide).

### Physics

The most difficult problems for urban trees are most often related to physical problems. Even apparent chemical problems often have a physical cause, such as salts rising where no natural rainfall occurs. The most important physical problems are related to compaction and restriction of gaseous exchange causing a drop in the redox potential.

### Compaction

<table>
<thead>
<tr>
<th>Ca/Mg ratio</th>
<th>High</th>
<th>Magnesite or Dolomite</th>
<th>Epsom salts</th>
<th>Epsom salts + Iron Sulphate or Ag Sulfur</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-6</td>
<td>Dolomite/ lime</td>
<td>no action</td>
<td>Iron Sulphate or Ag Sulfur</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>Lime</td>
<td>Gypsum</td>
<td>Gypsum + Iron Sulphate or Ag Sulphur</td>
<td></td>
</tr>
</tbody>
</table>
Soil compaction is the most important enemy of the urban tree in all close contact situations. All soils will compact under use by humans and this provides some severe problems for roots. Reduced extension, root branching and tip growth, reduced respiratory rate due to oxygen depletion and carbon dioxide accumulation, decreased nutrient availability, and a lower effective rainfall (reduced infiltration and reduced moisture holding ability) are all side effects (Craul 1992 pp 229-30). Ultimately, the longevity of the plant is affected.

Most soils contain a variety of particle sizes (an even particle size gradient) such that when compacted, close packing can occur with smaller particles filling the spaces between the larger particles until densities of over 1.9 g/cm$^3$ are created in the worst materials. It does not take much to fill up the spaces between the large particles so even a sandy material with much more than about 10% of a poorly structured clay starts becoming impermeable.

A soil which is missing one particular range of particle sizes is known as “Gap Graded”. These materials can be compacted and yet retain some pore space even under heavy loads. Extreme examples of gap graded soils with very large particles are termed “Structural Soil”. The use of gap graded sands to construct playing fields has been common for much longer. For a good discussion on the construction of sandy rootzones for playing fields see Adams (1994). Much of this science is directly transferable to arboriculture.

These gap graded or structural soils mimic natural soil where soil structure creates a natural gap gradedness. Thus the soil ped acts like a sand grain allowing water and gases to pass freely to greater depth. One very important difference is that sand grains do not hold any water whereas soil peds do, being composed of smaller particles and thus gap graded soil is prone to moisture deficit and if the rootzone is confined such as in a vault, will require irrigation.

Poor drainage.

Compaction, except in gap graded soil, will always result in a reduction in permeability. Many soils with a high silt and clay content have low permeability even when not compacted, particularly if poorly structured. Earthmoving during stripping or excavation usually degrades soil structure and hence permeability. Reduction in soil organic matter by eliminating the litter cycle is also a major cause or poor surface infiltration.

Poor drainage kills roots by reducing or eliminating gaseous exchange thus suffocating the root. This suffocation can occur over very short distances in saturated soil.

2. The Soil Profile

Natural soils form a strictly horizontal layering pattern which results from the interaction of climate, soil organisms and vegetation, acting on the parent material over
time in the given topographic position of the soil. These horizons are not accidental and nor are they inevitable. They form because the vegetation influences the soil largely through the process of bioaccumulation of limiting elements, and the effect that organic matter and litter has on the weathering and destruction of clay minerals. A typified soil profile based on an actual soil from a Blue Gum forest in Hornsby is shown in Figure 1.

A great deal of preliminary information can be gained from examining soil survey information from the area. Provided the area of interest is a largely natural soil surveys like the 1:100,000 series (eg Chapman and Murphy 1989) but most areas have their own surveys available) will provide good summary of the conditions likely to be found and the chemical and physical constraints of the soil.

This important interaction takes time, usually thought of in thousands of years. Observations made by ourselves over many years of examining soil profiles in disturbed environments lead us to believe that even after a few tens of years the re-establishment of the horizontation in a soil becomes obvious. More importantly, in a degraded soil Man can reduce, with soil ameliorants, this time period down to a few hours even. The important properties of a soil in equilibrium with its environment are-

1. Soil texture always gets “heavier” with depth except in deep sands.
2. Around 90% of the nutrient “pool” is in the surface 100-200mm.
3. Around 90% of the root activity of the vegetation occurs in the surface 100-200mm in most soils which are heavily textured with depth.
5. Gaseous exchange to and from roots gets slower with depth.
Figure 1. Typified Soil Profile.

- **O** decomposing organic matter and detritus
- **A1** Organic stained mineral horizon. S to CL in texture, mostly poorly structured (weak granular)
- **A2** Paler than A1, more acidic, often bleached Fe/Mn nodules ("shotgun pellets").
- **B1** Massive in the sandstone profiles, strong polyhedral structure in the shale profiles. Red, Yellow to white or grey with mottles in conditions of declining drainage or as you proceed down the catena. Zone of maximum clay.
- **B2** Transition zone to the weathered rock below. High clay but little stone.
- **C** Zone of weathered rock or parent material. Weathered rock inclusions.
- **R** The regolith, or parent material.

The distribution of nutrient elements with depth is illustrated in Figure 2. The other important factor illustrated is the influence of vegetation on the exchangeable cation properties. In this particular parent material calcium is much lower than optimal. Through bioaccumulation mechanisms calcium is accumulated in the surface biolayer to bring the topsoil calcium level close to optimal. Thus even where parent material is deficient in a particular element the topsoil can show quite abundant levels. This is illustrated by some actual data from a closed canopy Blue gum forest in Hornsby (Table 4).
The degree and maturity of the bioaccumulation equilibrium depends, most importantly, on the topographic position and the stability of the vegetation community. Fire, for example, opposes bioaccumulation and causes a loss of bioaccumulated elements both by direct loss as smoke during the fire and by exposing the soil surface to erosional forces after the fire. Slope position is also important, the tops of ridges being highly erosional environments where the hard won nutrients are continually washed away to accumulate downslope. In the downslope position the soil becomes deepened and enriched by this deposited material. Data from an actual toposequence study illustrate this in Table 5.

Table 4. Chemical properties down the profile of a Cumberland Clay Loam on shale.

<table>
<thead>
<tr>
<th>Chemical property</th>
<th>&quot;Ideal&quot;</th>
<th>&quot;Cumberland Clay Loam&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>5-7</td>
<td>Topsoil 4.7 Subsoil 2.8 Shale 7.0</td>
</tr>
<tr>
<td>Sodium (% of CEC)</td>
<td>&lt;5</td>
<td>2.8 8.3 37.0</td>
</tr>
<tr>
<td>Potassium</td>
<td>5-10</td>
<td>4.0 5.2 1.0</td>
</tr>
<tr>
<td>Calcium</td>
<td>60-75</td>
<td>58.4 2.8 2.0</td>
</tr>
<tr>
<td>Magnesium</td>
<td>15-25</td>
<td>33.0 37.1 60.0</td>
</tr>
<tr>
<td>Aluminium</td>
<td>&lt;2</td>
<td>1.8 46.5 0</td>
</tr>
<tr>
<td>CEC meq%</td>
<td>&gt;5</td>
<td>19.5 4.6 6.0</td>
</tr>
</tbody>
</table>
Organic Matter %  >2  10.5  0.2  0.1
Phosphorus mg/kg >5  7.6  1.1  0.0
(from: Leake 1996.)

Note from Table 4-
1. The extraordinary degree of bioaccumulation of calcium from 2% in the shale to 58.4% in the topsoil.
2. The relatively abundant level of phosphorus in the topsoil despite the low level in the shale.
3. CEC is directly related to the organic matter content.

Table 5. Soil Conditions Related to the Status of the Vegetation

<table>
<thead>
<tr>
<th>Determinant</th>
<th>E. gummifera Open woodland. Ridges</th>
<th>E. Saligna Tall forest Gullies</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>4.45</td>
<td>5.82</td>
</tr>
<tr>
<td>Total P in Topsoil ppm</td>
<td>170</td>
<td>469</td>
</tr>
<tr>
<td>Exch Cations kg/ha 0-61 cm</td>
<td>Na  94</td>
<td>443</td>
</tr>
<tr>
<td></td>
<td>K       430</td>
<td>1217</td>
</tr>
<tr>
<td></td>
<td>Ca      470</td>
<td>5032</td>
</tr>
<tr>
<td></td>
<td>Mg      765</td>
<td>3925</td>
</tr>
<tr>
<td></td>
<td>Al      4538</td>
<td>420</td>
</tr>
<tr>
<td></td>
<td>Ca/Mg by mass 0.61</td>
<td>1.3</td>
</tr>
</tbody>
</table>


3. The Special Problems of Urban Soils

When natural soil landscapes are imposed on for urban development many important changes occur to the soil, some of the changes have the potential to enhance and increase plant growth, others are highly detrimental. One of the best attempts to classify “Anthropic” soils is by Isbell (1996) in The Australian Soil Classification. We can further classify the changes that occur in order of least to most impact.

I. Natural soil left intact.

This is a common situation in most parks including many of our oldest city parks, but more obviously in new subdivisions and developments. Remnant natural vegetation often forms the structure of the new park. The classic changes that occur are-

a. Nutrient enrichment. The footprint of Man is nearly always elevated calcium, pH, phosphorus, and nitrogen status in the topsoil. This results from urban pollution (concrete and mortar, dog manure, cigarette buts, picnic wastes, urination and the general fallout of urban life). The changes are remarkably similar to condensing thousands of years of bioaccumulation and, often might be predicted to improve tree growth were it not for weed competition.
The profusion of urban weeds following the accumulation of calcium, phosphorus, and nitrogen is often eventually fatal to the remnant vegetation or greatly slows its growth rate, and is a big problem for the preservation of natural vegetation in urban environments. Harris 1983 (pg 357) gives an elegant example of turf affecting tree growth, the same will be true for vigorous weeds like Kikuyu. Such soils are termed “Hortic” by Isbell but this classification does not really include the “polluted” soils which have not necessarily been used for horticulture.

Some actual data from a Study in Melbourne by ourselves illustrates how important the influence of Man can be in assisting the forces of bioaccumulation (or is it polluting the soil). This is shown in Table 5.

Table 5. Crib Point Terminal: Natural and “House orchard” topsoil properties

<table>
<thead>
<tr>
<th>Determinant</th>
<th>Native Topsoil</th>
<th>Orchard Area Topsoil “hortic”</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH in CaCl₂</td>
<td>4.0</td>
<td>6.1</td>
</tr>
<tr>
<td>EC 1:2 dS/m</td>
<td>0.13</td>
<td>0.21</td>
</tr>
<tr>
<td>Exch Cations % of CEC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Na</td>
<td>5.1</td>
<td>1.1</td>
</tr>
<tr>
<td>K</td>
<td>3.0</td>
<td>3.3</td>
</tr>
<tr>
<td>Ca</td>
<td>47.0</td>
<td>80.9</td>
</tr>
<tr>
<td>Mg</td>
<td>38.5</td>
<td>14.7</td>
</tr>
<tr>
<td>Al(OH)²⁺</td>
<td>6.3</td>
<td>0</td>
</tr>
<tr>
<td>CEC meq%</td>
<td>4.6</td>
<td>14.0</td>
</tr>
<tr>
<td>Ca/Mg</td>
<td>1.3</td>
<td>5.5</td>
</tr>
<tr>
<td>Bray P mg/kg</td>
<td>&lt;1</td>
<td>13</td>
</tr>
</tbody>
</table>

Notice the important accumulation of calcium in the surface, most likely due to liming. Phosphorus, organic matter, Ca, pH, CEC are all showing “better” levels in the “improved” or “urban polluted” soil. These profiles were about 50 m apart. The orchard area still showed persistent European garden escapes, old fruit trees and weeds of high fertility such as Brome grass and thistles.

Apart from the encouragement of plants more responsive to the nutrients than the native species another important management aspect is that the accumulation of phosphorus can lead to decline and death of phosphorus sensitive species. This includes most of the Proteaceae, and many Rutaceae and Mimosaceae. Dying remnant Banksias showing red leaves and chlorosis are a classic symptom.

b. Compaction. A bunch of school children at a sports carnival on clay loam in a moist condition are just as effective as a good sheeps foot roller at destroying the structure and pore space of the topsoil and leaving it in a compact condition. pH rises because of the lower redox potential, oxygen levels fall, and slow decline of the remnants is inevitable.
c. Mowing and car parking. Open space is often used for spill over car parking, and the “neatness syndrome” results in rigorous mowing regimes. Compaction, depletion of soil organic matter levels and resulting erosion of the denuded surface is common.

II. Natural soil highly disturbed.

No longer are housing estates developed on a natural landscape but on a landscape totally altered to meet the planners ideal. Apart from the high environmental cost of this development process (fuel use, erosion and sediment runoff, loss of remnant species) it creates some profound problems in the soil-

a. Many trees are either lost or have their soil level built up, or cut away. Building up the soil level around a mature tree is nearly always fatal particularly for eucalypts and pines in our experience. If this is to be done the trees might as well be removed.

b. While most developers are aware of the importance of removing and reusing topsoil never, despite our best efforts, have we ever seen any consideration of the subsoils. Thus it is common to see a minimal amount of topsoil imposed right on top of deep C horizon material or even on top of cut rock (R horizon). Vegetation cannot reach its full genetic potential in this situation and toppling of tall fast growing species is common. Water logging due to impedance of subsoil drainage is common.

c. Jumbling and mixing up of horizons is common and the imposition of a clayey fill over a loamy topsoil will cause perching of water tables and a severe interface problem for moisture movement.

The Australian Soil Classification, Isbell (1996), describes Scalpic soils as those having lost their surface horizons, or Cumulic as those having been buried such as under an aboriginal midden or a filled area. Spolic soils are those formed from natural materials but in a disturbed and jumbled manner.

Another type of high impact is the imposition of surface paving over an essentially natural soil. This could be asphalt, concrete, or pavers. The effect is to reduce water infiltration and gaseous exchange. If the coverage of the rootzone is extensive enough and the tree species sensitive enough, decline is the common result.

III. Highly altered soils.

This general group consists of soils so disturbed that they bear no relationship to natural soil profiles and in some cases contain no natural soil component at all. It is hazardous to generalise about their chemical and physical properties and careful site assessment is always needed, usually by expert soil scientists. Some attempts to classify them Australian Soil Classification Isbell 1996) have been made but again, this classification is no guide to their properties the way it would be with natural soils-

- **Garbic** - composed of garbage and refuse organic and inorganic manufactured items, mixed with hard fill, clay, soil etc but with no horizontation apart from minimal organic matter accumulation at the surface.

- **Dredgic** - materials composed of dredged materials often from the sea. Very common in developed coastal area. Salinity and sodicity is often a problem.
Urbic - fill and disturbed material placed on top of a landfill at depth.

Problems that occur in these types of soils are many -

Salinity. Dredged soils are almost always saline when newly placed. With time and if permeable to some extent they desalinate leaving alkaline/sodic conditions and calcium depletion. Gypsum is a common requirement here. Acid sulphate conditions resulting from the oxidation of sulphides to yield sulphuric acid should be considered in low lying marine sediments.

Calcic Soil. Crushed demolition material can look much like soil but is nearly always overly rich calcium as a result of cement materials. There is often little that can be done except acidify the very surface with Agricultural sulphur, pH range 7 to 10.

Anoxia. The presence of organic matter buried at depth results in a demand for oxygen by respiring aerobic organisms. As the Redox potential drops various toxic by products occur including, in order of decreasing redox potential, ammonia, nitrite, manganous ions, ferrous ions, sulphide, and if things get severe enough, the landfill gas methane. Anoxic conditions can occur very close to the surface (a millimetre or less) when these soils are waterlogged but also occur in micro environments throughout even well drained garbic soils.

Nutrient imbalance. Throughout Sydney can be seen both quarries where nothing will grow for years and landfills where the Kikuyu and other weeds grows rampantly. While it is more difficult to remove nutrients, adding the missing elements after appropriate soil testing is usually a fairly simple matter. Where conditions are severe choose species suited to the conditions.

Compaction. During placement, or because of low organic matter and poor particle size distribution urbic soils can be extremely compacted showing densities over 1.6 which becomes highly limiting to organic matter cycling (bioaccumulation) root growth, nutrient uptake, heat insulation, and gaseous exchange (Craul 1992 pp 225-9).

Poor drainage. Compacted soils, apart from pure sands or “gap graded” materials, are nearly always highly impermeable, but poorly structured clay soils and those with an even particle size gradient can be impermeable even if not compacted. Gypsum is often needed due to sodicity but physical solutions such as drainage, resloping, and sand surfacing are often needed to fulfil planting aims. Impermeable subgrades provide the most challenging problems for the urban tree curator.

In summary the highly disturbed urban soil needs close site investigation before making decisions on amelioration as it is impossible to generalise from any soil classification scheme, what the properties will be. The aims of the planting are often restricted by the limitations of the site and budget. With good data and careful planning choices, however, even the worst sites can be made to successfully support some kind of tree planting.
Part II

Managing Soil Resources.

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In the first part of this series it was suggested that the soil environment is the overriding determinant of tree health. The most important physical and chemical principles governing the success of tree root growth were presented, illustrated by data. In this second part solutions to the most common soil problems are discussed with an emphasis on improving physical conditions.

1. Avoiding and Relieving Compaction

1.1 Compaction in Natural Soil Situations

Compaction and the attendant physical and chemical problems is the number one problem for the urban street tree as well as for turfed surfaces. Remnant trees on natural soils suffer from this very frequently given that natural soils are not usually gap graded. Given that the solutions can be very cheap it is inexcusable that so many remnant trees, sometime hundreds of years old, are left to die of neglect for want of a simple solution.

1.11 Removal of mowers and pedestrians

The simplest and cheapest method of saving old trees affected by traffic is to barrier the area to eliminate such traffic. A gradual build up of leaf litter will now occur, soil organisms will start the process of “pedoturbation” again, and a more natural cycle will commence leading to marked improvement in many cases.

It is pleasing to observe that this treatment has been used on nearly all tourist attraction trees now to their great benefit. The treatment can be combined with an application of mulch to start the process of litter accumulation. Fertilisers and soil ameliorants should also be used where soil tests indicate the need.

At the planning stage a great deal can be done to restrict most pedestrian traffic to “desire lines” away from trees. Groups of trees can have their rootzones connected into mulched beds planted with shrubs to reduce access and yet create a reasonably naturalistic appearance.

1.12. Mulching

Where trees have been neglected and the soil compacted such that litter cycling is eliminated and the soil has become compact and impermeable, a simple mulching very often has profound effects quite quickly. Immediately, the insulating properties of the mulch will improve the root environment, the lower run off quotient of a mulched surface will increase the effective rainfall and reduce evaporative deficit leading to
higher soil moisture contents and attendant decrease in soil strength. Trees will often improve markedly within weeks of this treatment showing a new flush of growth. In time roots can be see growing into the new mulch layer and proliferating at the O/A boundary.

A permanent improvement in tree health even with some continued traffic has also been experienced from simple mulching, the mulch absorbing some of the compressive forces. But as Craul 1992 pg 231 points out, it needs to be at least 6 inches thick and at this depth anoxia is a risk. We have also observed severe anoxia leading to death of trees when mulched about 6-8 inches thick (150-200mm) with their own freshly mulched prunings. If used for this purpose a mulch should definitely be well composted and have a low fines content and high stable wood content. Fresh leafy mulch should be definitely avoided. The treatment will probably not give good long term results where high level of traffic continue but may give a temporary improvement.

1.13. Ploughing to relieve density.

This method is used by farmers all the time. It provides only temporary relief in poorly structured soils as the soil will simply collapse again with rainfall. With continued pedestrian traffic even a well structured soil is simply going to compact again.

Cultivation does have its place however, especially where changes are planned to the access around an important tree. Accompanied by the installation of barriers to prevent access, or boardwalks around particularly important trees, the use of shallow and gentle chisel tyne ploughing in a radial direction away from the trunk can have some value in particularly heavily compacted situations where urgent intervention is needed.

1.14. Surface aeration

There are many devices available for relieving density in the soil. These range from conventional turf coring and slitting devices to the newer compressed air “terralift” type devices. Generally, methods for aeration of turf usually have a beneficial effect on tree root growth also.

The simple slitting and spiking devices only give temporary relief and in some cases the additional compression caused by the insertion of a spike leads to further compaction of the soil around the zone of zero density so created (See Handreck and Black 1994 pg 219). The only really effective process is to combine coring and slotting or deep slitting with a backfilling and topdressing of gap graded sandy material. In this way the large pore opened up by the equipment is kept open by the sand and does not simply compact again. The backfilling sand must be carefully chosen for the correct particle size range and may have some organic matter and fertiliser added.

A typical material would be a 90/10 mix of medium/coarse washed river sand with 10% of composted organic matter and some fertilisers especially lime and gypsum if needed. I would strongly recommend that mixes containing just compost not be used for such backfilling.
These treatments are well known to produce some profound responses in turf growth but are often overlooked as options for tree care. For a full discussion of the use of these methods and the design of the soil mixes see Handreck and Black (1994) and Adams (1994).

### 1.15. Surface grating and other treatments.

The use of plastic or masonry open grating as a surface treatment where car parking and heavy pedestrian use occurs is becoming more common. There is little data around on the actual improvement to trees but on theoretical grounds the better infiltration, insulation, and compression bearing should result in improvements to tree roots as it does for turf.

Surface treatments like paving present problems of reduced gaseous exchange even where so called porous paving is used. Such restriction also occurs from filling over rootzones will soil or fill. In both situations a similar technique is used to admit a free atmosphere to the old original soil surface.

The usual method is to use coarse gravel aggregate and perforated agricultural drain pipe in a cobweb pattern away from the tree, to ensure the free flow of air. It is important that the ends of the piping remain open to the atmosphere via vent holes and this can provide some difficulties where these are exposed to the public. The vent pipes can be used for irrigation. Where trees are deeply filled, or the soil level brought up significantly it is most important to ensure adequate drainage but given the elimination of litter cycling and natural processes, some reduction in longevity of the tree could be expected. We have observed trees show no detrimental effects at all with up to 2/3 of the rootzone covered in this way.

Surface grates around the stem of trees are really just to allow expansion of the trunk and do not really have any impact on the gaseous exchange unless accompanied by a porous layer with vent pipes open to the surface.

### 1.16. Soil replacement.

Where a particular soil has very unfavourable physical nature such as a silty clay loam, and traffic cannot be reduced, one of the only options left is to remove the soil and replace it with a gap graded material. Watson 1990 (reported in Craul 1992 pg 239) reported good stimulation of new root growth into a sandy medium used to replace the surface of a compacted soil. The technique used was to remove trenches of soil from between the main trunk roots radiating out from an established tree and replace it with a soil compost mix.

Together with Sydney City Council we used a related technique where we removed the entire compacted silty loam surface soil by hand to about 100 mm from around some trees in Hyde Park Sydney and replaced it with a gap graded material. We did not use Watson’s method of placing geotextile fabric over the sandy material to prevent turf roots from competing with tree roots and the health of the trees and the turf improved markedly.
In this context it is worth mentioning that services backfilled with sandy materials as is usually specified by engineers virtually invites and local tree roots to enter the material. We have seen this many times and in some highly restricted rootzones of city trees it may represent the only effective rootzone the tree has!

1.2. Compaction in Confined Rootzone Situations.

Extreme cases of confined rooting volume and continuous heavy traffic such as city street tree plantings call for more extensive engineered solutions. In some situations such as holes dug in rock, the situation is effectively a fully containerised planting. In other places where some soil still exists under footpaths, a half way situation occurs.

1.21 In ground planting.

There are two solutions commonly used to solve this problem, suspended slab vaults and structural soils. Another paper in these proceedings discusses structural soil in detail, but to summarise the approach a “soil” is constructed of large sized gap graded aggregates capable of taking the full compressive force of roadways and footpaths while still maintaining sufficient pore space and size between the aggregate particles for root extension. No pier or suspended slab is needed.

Suspended concrete slabs are used often in such situations as fully containerised indoor planting, foyers, etc in buildings. Rarely are the costs justified in outdoor treescape planting. The most important aspect of this type of planting is that a gap at least 50mm deep is allowed between the bottom of the cast slab and the top of the soil medium. Great care must be exercised to keep this gap open to the atmosphere, we have seen situations where the gap was closed up at planting by excess amounts of soil and anoxia resulted.

Some good design details of tree pits or vaults are available in Craul 1992 pp 296-7. Note that they allow for a layer of gravel sandwiched between the bottom of the suspended slab and top of the rootball soil, in my opinion and air gap would be preferable but the rest of the detail is exactly as we have specified in the past.

A typical detail would look something like Figure 1. Note that drainage of the confined rootzone is essential if the subgrade is impermeable, if a “swimming pool” is to be avoided.

1.22 Containerised planting.

Fully containerised situations without the benefit of the nutrient and moisture buffer reserve that access to soil brings, always requires more maintenance in terms of irrigation and feeding than when soil is available.

Designing soil mixes for these situations requires an appreciation of several factors-a. What weight restriction might occur on the slab or planter box. We usually try to design for a worst case scenario where the planter box becomes fully saturated thus we design a mix for a certain density in the fully saturated condition.
A concrete slab with a bearing strength of 20 kPa is capable of taking a load of 2040 kg/sqm (1 kPa = 0.0102 kg/cm²). Therefore, if the bed is to be 1m deep we can accept and all up saturated density of 2040 kg/cubic metre. If the bed is 1.5m deep we must design for a saturated density of 1360 kg/m³.

In our experience is very difficult to design a mix for less than around 1400 kg/m³ even using light weight materials. 2000 kg/m³ would provide few problems for design. Suitable light weight mineral materials to reduce density are horticultural ashes, pumice, perlite and expanded calcined clays (eg kaolite).

b. The organic matter should not be buried more than around 300 mm. We discussed in Part I how natural soils never contain organic matter at depth. The danger is that further decay of the organic matter sets up an oxygen demand at depth even in well drained materials. All organic matter will decay but particularly dangerous in this situation is fresh organic matter such as Mushroom compost. Peat and coconut coir as well as some well stabilised pine bark products can be used in small proportion. Thus we design mixes so that inert mineral matter such as light weight ash dominates the mix, we can only use high proportions of sand if there are no weight restrictions. This is discussed further under Preventing Anoxia, below.

c. That collapse and settling of the mix will occur if biodegradable components are used. Planter boxes are usually required to remain in place without the need for constant repotting and at least 3 years and sometime much longer is desirable. Another good reason not to use too much organic matter is that it decays and settles in the container resulting not only in a drop in level but a collapse of pore space further exacerbating any oxygen deficiency. Pine bark, peat, and coir are less prone to rapid decay.

We would recommend the same two layered mix situation as is shown in Figure 1 only, for light weight planters typical mix composition for the A and B mixes would be:

A Mix 300mm deep only.

Graded and washed Ashes or similar light weight material. 40 %
Coarse Sand 20 %
Loam Soil 10 %
Composted Pine Bark 20%
Manure or similar rich Organic Matter 10 %

B Mix

Graded and washed Ashes or similar light weight material. 50 %
Coarse Sand 30 %
Loam Soil 10 %
Composted Pine Bark or similar stable organic matter <10%

Note that Figure 1 shows a sand/soil mix as the B horizon material. This is acceptable where no weight restrictions occur. The most important aspect is that the B layer is predominantly (>90%) mineral in nature.
The reader is also referred to Couenberg (1993) for a description of the “Amsterdam Tree Soil” mix which uses a similar philosophy.

Figure 1. General Planting Detail, Two Layered Mixes

2. Preventing and Relieving Anoxia

In our experience the most common source of problems in tree planting both in soil, disturbed materials, and in planter boxes and engineered situations is a drop in Redox potential associated with oxygen consumption in the soil.

2.1 Planting in Soil.
The extraordinary diagrams that Watson (1997) showed of the root system of an oak should put paid to the notion of tap roots and drip lines forever and his use of the term “root plate” is an elegant summary of the actual situation.

A new transplant, unless it is bare rooted, has a very different root structure with the roots confined to a ball in a very artificial manner. The fact that root density in the pots is often highest at the bottom of the pot, plus the use of highly organic potting media can combine with exacerbating circumstances such as heavy rain and/or impeded drainage to produce anoxia in the lower half of the root ball. The diffusion equations predict that oxygen can become limiting even over very small distances in water filled pore space so the problem occurs not only for large stock but for tubestock as well.

This is seldom a problem in drier climates and perfectly drained soils like sands where saturation of the soil is unlikely, but certainly contributes to the death or slow establishment of many new plantings in humid zones when heavy rain occurs on soils with impeded drainage. The classic symptom is wet soil, leaf drop, root death from fungal disease and suffocation, the smell and colour of rotten egg gas, with only a few roots remaining at the very surface of the soil from which the plant must try to establish a new root system adjusted to the Redox conditions found.

This an old problem and solutions such as mounding are often recommended. In our experience there are a couple of more effective things that can be done:
1. Virtually bare root the plant rootball by washing off all organic potting mix and spread the roots out in a plate like manner no deeper than 5-10 cm less in wet conditions.
2. Backfill the planting hole with a sand or very sandy loam with some fertiliser present but strictly no organic matter.

The damage done to the root system may require some cut back of top growth but will soon be made up for if the conditions presented are more favourable. In a wet condition the bottom of the rootball is almost certain to die anyway.

Wherever wet conditions are likely or even possible, and soil texture is such that restricted drainage is possible we would recommend that organic matter never be incorporated into the planting hole before placement as is often recommended. The improvement in water holding this might bring is more than offset by the danger of even brief periods of anoxia.

The incorporation of organic matter into subgrades and backfilling mixes is only advisable where drainage is perfect and there is a need to improve the water holding, cation exchange capacity, and organic matter content of a degraded soil.

When planting large rootballs, the two layered mix described above should be used. To improve interface problems between a sandy backfill mix and a heavier site soil use 10-20% of the site soil itself in the backfill mix instead of imported sandy loam.

2.2 Planting into Containers
Containerised situations have been discussed in terms of two layered soil mixes and “Amsterdam Soil” mixes. This technique will reduce the tendency for very low redox potentials to develop even when waterlogging does occur.

We have seen examples however where even low levels of reasonably stable organic matter in planter mixes caused anoxia and sulphide production even though drainage was not impeded at all. At the Capita centre in Sydney we deliberately designed a mix for low organic matter using about 20% composted pine bark and 10% peat in beds up to 1300 mm deep. The newly installed mix showed anoxia leading to sulphide production which could be smelled upon auguring. Table 1. Shows some qualitative results from this exercise-

Table 1 Incidence of sulphide odour with time and Depth at Capita Centre.

<table>
<thead>
<tr>
<th>Depth mm</th>
<th>Sulphide Smell at time given</th>
<th>Yes/No</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 week</td>
<td>2 week</td>
</tr>
<tr>
<td>Surface</td>
<td>slight</td>
<td>no</td>
</tr>
<tr>
<td>300 mm</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>600 mm</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>900 mm</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>1200 mm</td>
<td>yes</td>
<td>yes</td>
</tr>
</tbody>
</table>

The simple qualitative data shows that when first installed, the rotten egg smell of sulphides developed almost to the top of the bed. As the organic matter further decayed and stopped demanding oxygen, conditions gradually improved until by 8 weeks (about the time it takes to compost organic matter) the smell had virtually disappeared except right down the bottom of the bed where the soil mix remains rather wet.

Plants in distress from anoxia are usually suffering not just root suffocation and the attendant wilting but can suffer increase root fungal disease problems and, if conditions are severe enough, sulphide poisoning which results in leaf drop and deformation of growing leaves but stress and reduction of root growth occurs even without sulphides being present.

The only really effective long term cure for plants sitting in rotten smelly wet organic mix is to remove the plant and replace the soil but in less extreme situations a number of options are of help-

1. auger holes down the full depth of the planting medium just outside the rootball. These should be backfilled with a slotted Ag pipe to keep them open and will admit air straight to the bottom of the mix where it is needed. It will also allow the toxic gases to leave and generally re-establish oxidising conditions.
2. Dig an annulus shaped trench around the rootball replacing the mix with a very open low organic mix.
These treatments are not going to work unless the source of excess water is removed but in situations where excess water is not a factor, they have worked very well in some cases for our clients trying to save new transplants in critical condition.

There is little, in our experience, that can be done about soil borne fungal rots. Even drenches with strong fungicides like Terrachlor producing no apparent improvement.

In summary, by providing a medium which has a far greater macroporosity than normal soil, we can overcome the physical limitations of natural soil that only allow roots to function in the surface, to allow roots to function throughout the container volume provided. Thus we can compensate for restricted lateral volume by providing depth to the container.

3. Feeding and Watering.

Unfortunately there is very little useful data available on water use in Australian trees although some data is available on exotic species (See Craul 1992 pg 252). This, together with the fact that the Australian climate is so extremely variable makes the calculation of rooting volumes based on water storage requirements very difficult and of dubious value.

American data reported by Craul (1992) suggests that 600 cubic feet (17 cubic metres) was associated in one study with large healthy trees but that half this volume (8 cubic metres) was associated with adequate vigour in larger tree specimens. There are various other approaches to rooting volume calculations.

In a totally confined rooting space the provision of irrigation is usually essential in Australia even if it is only needed on a supplementary basis. Attempts to use conventional agricultural water budgeting calculations in confined tree situations are so fraught with assumptions as to provide little of any real value. Where we have seen people attempt to do this and to run automatic computer watering systems based on these assumptions, problems of (usually) over watering are common. Being based on long term average climatic statistics it is not uncommon to see irrigation switch on at the appointed hour despite the fact that it actually raining!

A more intelligent approach where automatic irrigation is planned is to use tensiometer sensors to control the switching. Problems of short life of tensiometers, hysteresis effects, soil/tensiometer contact provide some difficulties here but the method is used in agriculture and should gain more widespread use in arboriculture.

In manual irrigation systems there is one golden rule that is almost never observed. Examine the soil before you irrigate, if the soil is moist to eye don’t bother. Your examination of the soil should ideally include the whole profile. Dryness at the top and wetness at the bottom will tell you something about root distribution and the needs for mulches.

Irrigation of distressed mature trees will often bring about an improvement. Anyone who has observed the flush of new growth that occurs in our Eucalypt forests within days of rain will attest to the importance of not overlooking dry soil as a stress factor which should be eliminated. Remember also that moist soil is not as strong as dry soil
and in the softer moist soil root extension could be expected to be faster. A combination of the surface soil treatments to relieve compaction that were discussed above, and a good drink can produce wondrous effects. Do be careful of overwatering however as we do not want to waterlog the new mulch and loose soil.

Fertilisation of trees

Fertilising can be conveniently divided into two basic aims, adjusting soil properties for optimal nutrient availability and physical properties, and secondly providing those macro and micro nutrients which tests indicate are needed.

The first aim uses what we would term soil “ameliorants”. Products such as lime for pH adjustment or gypsum for Ca/Mg ratio adjustment are not necessarily used because a plant is experiencing calcium deficiency (or sulphate in the case of gypsum) but for their beneficial effect on soil pH, and calcium/magnesium ratio (and hence physical properties).

These basic soil ameliorants should never be used in a “recipe” book fashion, that is used regularly as part of a maintenance program. They should only be used as soil tests indicate they are needed. We saw in Part I of this article how it is very difficult to predict the properties of an urban soil from some regional character that the natural soils might show. The urban soil based on the naturally acidic soils of the region may, for example, have been contaminated with cement runoff during construction and hence now be alkaline and excessively calcium rich. A regional recommendation from the Dept of Agriculture to add lime could make problems worse.

Table 3 in Part I of this article can be used to decide which of the basic soil ameliorants must be used after having soil tests performed. Table 1 below is an indication of how much of these products must be used. Gypsum requirements can be directly calculated from the results. For example, we have a soil with a CEC of 12 meq% showing only 40% exchangeable calcium. We want to boost it to 60% or an additional 20% of the 12 meq% exchange capacity. Thus we need an extra 2.4 meq%. Using the calcium content of gypsum of 23.3% and the fact that there are 2 equivalents of charge per mole of Ca and 40 grams of calcium per mole we can exactly calculate that:

\[
\frac{2.4 \text{ meq}}{100 \text{ g soil}} \times \frac{1 \text{ mole}}{2 \text{ eq}} \times \frac{40 \text{ g Ca}}{1 \text{ mole}} \times \frac{100 \text{ g gypsum}}{23.3 \text{ g Ca}} = 2.06 \text{ grams gypsum/kg soil}
\]

Some depth, density, and area assumptions can then be made to formulate a very precise recommendation for gypsum addition. Gypsum is actually reasonably soluble (2 grams per litre of water) and thus can be surface applied and watered in. When treating the sides and bottoms of tree pits in clay soils the use of a solution of gypsum at 2g/litre is sometime the only way it can be used as it is hard to get the powder to stick to the side of the pit! Gypsum is often used in these situations to prevent clay dispersion which threatens drain life.

Table 1. Approximate amounts of Calcium Carbonate to use in soils of different texture.

<table>
<thead>
<tr>
<th>Soil Texture</th>
<th>grams lime per sq m to the stated pH change</th>
</tr>
</thead>
</table>

Sydney Environmental & Soil Laboratory
<table>
<thead>
<tr>
<th>Soil Type</th>
<th>pH 4.5 to 5.5</th>
<th>pH 5.5 to 6.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand, loamy Sand</td>
<td>85</td>
<td>110</td>
</tr>
<tr>
<td>Sandy Loam</td>
<td>130</td>
<td>195</td>
</tr>
<tr>
<td>Loam</td>
<td>195</td>
<td>240</td>
</tr>
<tr>
<td>Silty Loam</td>
<td>280</td>
<td>320</td>
</tr>
<tr>
<td>Clay Loam</td>
<td>320</td>
<td>410</td>
</tr>
<tr>
<td>Organic Soil</td>
<td>680</td>
<td>790</td>
</tr>
</tbody>
</table>

From: Handreck and Black 1994 pg 92.

The only other aspect that must be kept in mind when using liming agents (remember your soil tests might indicate that a dolomitic limestone is needed) is that different sources of alkali have differing neutralising ability thus 100 grams of lime is equivalent to about 90 grams of dolomite, 75 grams builders lime (calcium hydroxide), and 56 grams of quick lime (calcium oxide).

Calcium hydroxide is sometimes recommended because it is more soluble, acts faster, and can be watered in, at least to shallow depth which calcium carbonate cannot. Calcium carbonate is normally surface applied but reacts faster if ploughed in to the soil. Where this is not possible use the hydroxide or add lime to the topdressing medium or sand backfill in a coring and slitting exercise. Surface applied lime is not useless since with time the normal soil processes will result in some effect at depth.

To neutralise an acid soil at greater depth without repotting the containerised plant, and even in soil, a two stage process can be used. Firstly water in potassium hydroxide, a very soluble alkali-

\[
\text{KOH} \quad \rightarrow \quad \text{K}^+ \quad + \quad \text{OH}^- 
\]

then water in gypsum -

\[
\text{CaSO}_4 \quad \rightarrow \quad \text{Ca}^{2+} \quad + \quad \text{SO}_4^{2-} 
\]

The calcium will then react with the hydroxide to yield calcium carbonate. We have thus manufactured lime at depth by applying two soluble salts which react together to give an insoluble one, lime. Do not use this method without very careful laboratory analysis to determine the precise amount of potassium hydroxide needed, this is a strong alkali and can easily be over used (it is also highly caustic and potentially hazardous).

Using acidifying agents it must be recalled that pH and buffering capacity are not related. Thus a soil with a mildly high pH of say 7.1 may contain a lot of lime. Given that 32 grams of sulphur is needed to neutralise 100 grams of lime then a soil with a lime content of say 5% is going to need around 2 kg of sulphur per square metre to neutralise all the lime in the surface 100mm, a potentially expensive exercise. For this reason it is often necessary to choose lime tolerant plantings on limey soil rather than rely upon acidification.
The need for macronutrients N, P, and K should also be assessed with soil tests or with experience in the soil type given. It is not necessary to state that plantings in artificial growing media are going to need regular fertiliser use in order to maintain the desired growth rate. This is done most safely with controlled release fertilisers supplemented with liquid feeds. It is dangerous to use soluble solid fertiliser dressings in any confined rootzone situation as the degree of dissolution of the fertiliser is very unpredictable and may result in salinity problems. Products like Nutricote, Osmocote, and proprietary liquid feeds provide a safer solution.

In ground trees may or may not need feeding. It is often stated in texts that such trees need regular feeding despite the fact that most of the mature trees in our parks have grown up without any fertiliser at all! The decision to feed should be based on consideration of the condition of the tree (we might want to use fertiliser to improve vigour in a poor specimen), and the desired growth rate (we want a faster attainment of size).

Nearly all new plantings will benefit from the use of fertiliser in the planting hole. Only long term slow release fertiliser should be used which is less available to the local weeds and turf roots. The use of a manure enriched imported surface layer may obviate the need for any fertiliser at planting.

The desired NPK ratio of the fertiliser should be established first by soil testing or experience. Thus soils tests may reveal that we may not need any potassium but a large amount of phosphorus and nitrogen in a newly planted soil and choose an NPK of 10:8:0. Blood and bone with some superphosphate added could be ideal. In another situation in a golf course, for example, we may need no P due to incessant use in the past, but a high K level and choose an NPK of say 8:1:6, a Native Plant food fortified with some sulphate of potash might be ideal.

When feeding mature trees keep Watson’s (1997) cross section of a tree’s root spread in mind. Any notions about feeding at the drip line should be abandoned and fertiliser spread over the entire area up to twice the tree’s height away. Where fertiliser cannot be ploughed in or added to sandy coring and slitting back fill media then more soluble forms should be chosen so that they will water in to depth where they are needed. This is most usually a problem for phosphate salts and ammonium and potassium phosphates (eg MAP and DAP) are the only readily available form of soluble phosphate. All fertiliser salts of nitrogen and potassium are soluble.

Conclusion

Our understanding of the physical constraints placed on the rootzones of urban trees has advanced greatly in the last 10 years to a point where reliable techniques to prevent and to remediate problems in the rootzone now exist.

The main problems which face our urban trees are related to compaction and anoxia. These problems are prevented by the use of Gap Graded soils which range from sandy turf underlay materials to specially designed structural soils.
The problem of the decay of organic matter causing oxygen consumption is avoided by not using organic matter below 300mm in most planting situations or by using only very stable organic matter such as peat or well composted pine bark in small amounts.

Designing to avoid problems is always preferable to rectifying problems but the experience now exists to give confidence that most situations can be rectified by a variety of remedial methods such as fertilising, replacing compacted soil with gap graded materials, surface and subsurface aeration, protection of the surface from traffic, and irrigation.

It is only by a full understanding of the physical and chemical constraints and careful site analysis that the correct methods of design and remedial work can be chosen. Experience suggests that considerable improvement in the health and longevity of our urban trees is possible through such understanding and the application of some of the new techniques emerging from the research and from field experience.

References:


