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SOILS, WATER AND TREE ESTABLISHMENT

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INTRODUCTION

My observation of tree performance post-planting suggests that the first few months after planting are critically important in tree success. Many planting failures are due to problems with water supply (too much or not enough). The bigger the tree at transplant and the drier the weather at time of planting, the more difficult the project will be to manage from a water point of view.

In this paper I will outline some of the basics of water movement in soil and then I will specifically address the management of tree water supply post-planting.

SOIL BASICS

Soil is a particulate material. Soil particles have a range of sizes and the combination of particle sizes in a soil determines its texture. While many soil properties can be inferred from texture, in many cases it is essential to actually measure the property in question, rather than rely on an assumption based on texture. An example is the infiltration rate of soils. It is very difficult to accurately forecast the infiltration rate of a soil just by examining texture and in some applications, a laboratory measurement is essential to ensure adequate performance.

The particles in a soil may or may not be combined into larger units or aggregates. This phenomenon is called soil structure. The soil particles may or may not be unnaturally crowded together by physical pressure at the surface (compaction). Both aggregation and compaction modify soil properties. Because urban soils are so disturbed and unpredictable, an assessment of soil texture, structure and compaction at a planting site is one of the essential checks that should be done so that plant selection and site preparation and management are able to address potential problems at the site (Smith and May, 1997).

Soil particles/aggregates do not occupy all soil volume. There are spaces between particles (pores) that form a continuous network of channels through the soil. The pores contain water, air, plant roots, nutrients, micro-organisms and macro organisms. The proportion of a soil's volume that is pore space is called the porosity of the soil.

Bulk density gives a measure of the level of compaction. In sandy soils in good condition (loose and non-compacted) it ranges from around 1.2 – 1.6 t/m^3. In such soils porosity is typically around 40-45%. In fine textured soils (loams and clays) in good condition it ranges from 0.8 – 1.2 t/m^3 (porosity in these soils typically being in the range 50-60%).

In most circumstances, water enters soil at the surface, moving through the pore spaces.

Oxygen also enters soil at the surface. Oxygen molecules diffuse through open pores (oxygen diffusion is very slow in water) following concentration gradients downwards (soil typically has lower O_2 than the atmosphere because of respiratory activity in the soil). Similarly, the CO_2 produced by respiration diffuses out of the soil through open pores.

The rates of O_2 and CO_2 diffusion into and out of soil respectively are the property we call soil aeration. For soil to be well-aerated, there must be a relatively large proportion of pores that do not contain water. These are the large diameter pores called macropores by soil scientists. The property air-filled porosity (AFP), known to nursery growers, is a measure of the macroporosity of a potting mix. The concept is essentially similar in soils. The basics of soil and growing media are dealt with in Handreck and Black's '*Growing Media for Ornamental Plants and Turf*. Every horticulturist should own a copy. For a detailed description of how these basics apply to urban soils and their interaction with plants, Craul (1992 and 1999) is hard to beat.

WETTING

Two forces drive water movement into soil. One is gravity. This is most active in soils with large diameter pores (coarse sands, soils with strong structure, cracks, and biopores). In fine textured soils, wetting occurs as a result of the attraction of water molecules to surface of particles (adhesion) and for each other (cohesion). In this case water movement can be almost as fast sideways as vertically. The rate of water movement into soil is the infiltration rate (mm/hr) and can vary from thousands of mm/hr to fractions of mm/hr. High infiltration rates are found in sands and in well-structured loams and clays. Low rates are found in poorly-structured loams and clays or in soils that are heavily compacted.

In the field, measurement of this property is done using an infiltrometer. Laboratory measurement determines the saturated hydraulic conductivity (SHC) of disturbed samples (used in Australian Standard AS4419-2002 Soils for Landscaping and Garden Use). As a soil is wetted, a layer of soil close to saturation develops. As the wetting continues, this layer moves deeper into the soil. It is separated from the dry soil beneath by the wetted front, a very narrow zone where moisture content changes from saturated to the original level. If soil porosity changes occur in the soil profile, the rate of movement of the wetted front will be affected. Smaller pores with a lower infiltration rate or SHC will slow the movement of the wetted front and water can 'back up' above this layer (as occurs with heavy clay subsoils).

Perhaps counter-intuitively, larger diameter pores will stop water flow altogether until the soil above is saturated. Only then will water flow into the large pores. This happens with drainage layers or pipe drains and also occurs with potting mix in root balls. Once the soil is saturated, water can then flow into the large diameter pores of the coarser material. The effect of this will be discussed later in this paper. McIntyre & Jakobsen's *'Drainage for Horticulture and Sports Turf'* is an excellent publication for understanding this phenomenon better.

When water application stops, the situation is as follows. In the pores there are water molecules at varying distances from particle surfaces. Those furthest away are held loosely, those closest, tightly. The dry soil beneath is still attracting water molecules so the most loosely held will continue to move down, emptying the centres of the larger pores. Eventually the two forces balance and water movement stops. At this point, the soil is said to be at field capacity and this marks the upper limit of moisture retention by the soil. From this point, the main mechanisms for soil drying are surface evaporation or transpiration (that is, by plant root uptake). Flow as a liquid into dry soil is extremely slow once field capacity is reached.

At the point where the soil is so dry that plants can no longer obtain water, the soil is said to be at wilting point, even if wilting is not observed (common in xeric species). The amount of water held between field capacity and wilting point is called the available water content of the soil and knowledge of this is used to schedule irrigation. Table 1 shows these values for several Australian soils and is used for illustration only. Note that in general, as clay content increases, water held at field capacity and at wilting point and available water all increase.

Table 1: Soil water content in several soils (from Leeper and Uren, 1993)

Soil	Moisture content @ field capacity	Moisture content @ wilting point	Available water
Winkie S	6.2	2.4	3.8% 5.7 mm/100mm soil
Tatchera SL 0-75 mm	17.6	8.4	9.2% 13.3 mm/100mm soil
Berwick CL 0-75 mm	44.7	30.2	14.5% 12.3 mm/100mm soil
Grenville C	32.4	14.6	17.8% 30.0 mm/100mm soil

COMPONENTS OF THE PLANTING ENVIRONMENT

Once planting is complete, the tree can be seen as being part of an arrangement where there are three related systems. Each system has its own characteristics and has to be treated differently to get the best out of the whole arrangement. The three systems are the root ball, the backfilled planting hole and the landscape soil. Table 2 summarizes the characteristics of each of these.

Table 2: Characteristics of the three component systems of a planting

System	Physical condition	Root density	Rate of drying	Need for irrigation to ensure success of planting
Root ball	High AFP, low bulk density	Very high	Very rapid	Critical and possibly frequent
Back fill	AFP and bulk density potentially high and low respectively	Nil at planting	Very slow	Important but very low frequency
Landscape soil	Variable, may be poor	Potentially high	Variable depending on vegetation	Not important in the short term

Following planting, the tree relies on water in the rootball until such time as it can grow new roots and invade the backfill. As more roots invade the backfill, the tree is then able to exploit the water held there and becomes less dependent on the water in the rootball. Under good conditions root growth can occur quickly but the rate of rootball drying can also be very rapid (Watson, 1993). Plants can use the water held in the rootball very quickly and if the rootball dries out the results can be root tip death, stress, hydrophobicity of the rootball, shoot die-back and even whole-plant death. To add to the problem, once planted, a container rootball holds less water than it did in the nursery (Gilman, 1990). While common sense would say that post-planting water stress will be a particular problem when planting happens in the warmer months, I have seen this happen in Melbourne in winter during dry spells.

Because of the relationships shown in table 2, the short term water need is greatest in the root ball. In the period immediately following planting, water should be directed to the rootball. There is little point irrigating the backfill as there are no roots there. If water is directed to the backfill, the backfill has to be saturated before water will flow into the rootball. Not only is this wasteful but it also means that there is potential for the backfill to be over wet, resulting in low soil oxygen levels and further limiting new root development. This will especially be the case where the landscape soil is impermeable and water delivered into the backfill cannot drain into the subsoil.

The best results will be obtained where the rootball and the backfill are irrigated separately. Drippers or a water holding basin will be the two simplest ways of delivering water to the rootball. In the case of drippers, they have to be installed on top of the rootball. In the case of a watering basin, the wall of the basin should not extend beyond the edge of the rootball. In addition to careful placement of irrigation water during this critical period, it is valuable to have some idea as to the amounts of water involved.

A WORKED EXAMPLE

Consider a container-grown tree approximately 2 – 3 m tall, typical of the kind of stock being planted in Australian cities at the moment. A typical container for this type of stock is 460 mm wide with a root ball depth of 270 mm. This gives a root ball volume of 45 L. In potting mixes, the available water is about 30% by volume so to rewet from wilting point to field capacity will take around 13 L. This calculation assumes that the water is being directed to the root ball and that there is no runoff down the sides of the root ball. If watering was through the use of a basin the same width as the rootball, directing water into the rootball, a wall depth of 75 mm holds 12 L, of 50 mm holds 8 L and of 25 mm holds only 4L. While this is probably the simplest solution for most tree managers to use, maintaining the high soil wall needed to deliver enough water is difficult in practice. Plastic planting rings serve this same function and the volume of water they contain is easily calculated. Being plastic they obviously are more durable than an earth wall. Bear in mind that if the ring is wider than the rootball, much of the added water will run around the rootball rather than into it.

If planted in a sloping sided hole, three times the width of the rootball, the volume of the backfill is 150 L and the volume of the entire system is 195 L. If watering is by wetting the backfill, it is first essential to saturate the backfill before water can flow into the root ball. This could take 75 L of water but will depend on how dry the backfill soil is. Use of slotted pipe to rewet the backfill will be of little benefit immediately after planting. Two lengths of 75 mm pipe, 270 mm long only hold 2.4 L of water. If run in a circle around the base of the pot, this increases to 6.4 L. In neither case is this near enough to saturate the backfill, allowing water to flow into the rootball. That is, slotted pipe watering systems will be ineffective before the tree has roots growing in the backfill. Once the tree has started to colonize the rootball, slotted pipe will be of some use but clearly can only supply a small volume of water. They are satisfactory in the “any water is better than none” scenario but where there is a requirement to deliver large volumes of water to a tree they have limitations. For trees planted out of smaller containers, the slotted pipe may be relatively effective because the trees are smaller and their rate of water use is less but again, will only be useful once roots escape the rootball.

RATES OF WATER USE BY TREES

How much water does a tree actually use during establishment? The answer has many components as it depends on the size of the tree, the species of tree and the weather at the time of concern. Table 3 shows estimated weekly rates of water use by trees in Melbourne (G. Connellan, *personal communication*).

Table 3: Weekly water use by trees of different sizes (Melbourne)

	Water use (L/week)		
Crown diameter (m)	Summer	Autumn/Spring	Winter
0.5	10	5.5	2
1.0	40	22	8.5
2.0	158	87	34

These values are based on average daily evaporation data and across a week are probably satisfactory from a planning point of view. Bear in mind however that a very hot windy day could double or triple the rate at which a tree uses water. Looking again at the worked example above, these figures tell us that if that tree was planted into a landscape project in summer then it has just over one day's water in the root ball. In winter we would expect it to last for 5-6 days before irrigation was needed (assuming no rainfall). Adelaide has a warmer climate than Melbourne and these water use figures may be up to 20% higher in Adelaide for the same species.

SOIL MODIFICATION TO IMPROVE PERFORMANCE?

Organic matter and gypsum

In many Australian soils the physical condition of the soil can be improved by adding gypsum and/or composted organic matter. These treatments result in more soil aggregation and improved aeration of the soil. Ideally the whole planting site should be treated before planting (10 L of composted organic matter and up to 1 kg of gypsum per square meter would be typical rates of application). If only incorporating organic matter into the backfill, care must be taken. If the organic matter is incorporated too deeply (greater than 200 mm) anaerobic decomposition can occur. Root growth will not occur in the absence of oxygen. This problem also occurs with highly organic landscape soils and planter mixes and these should not be used as backfill soils.

Mulch

Mulching the planting site can reduce evaporative water loss and is to be encouraged in most plantings. The entire backfill and rootball area should be mulched. Mulch can also increase the rate of water infiltration and obviously also has some role in weed suppression. Research suggests that coarse textured mulch used at a depth of about 75 mm gives the best results. There is an Australian Standard (AS 4454-2002) for composts, mulches and soil amendments and this should be used more often to set quality specifications for landscape project materials.

There is also an interesting question about mulch use to resolve and that is whether or not mulch placed around the lower trunk is a serious problem. Many people argue that mulch placed close to the trunk causes injuries but I'd be interested to hear some experiences on this. Fresh chipped prunings may well be quite a different proposition to material that has been through a composting process.

Water-absorbing gels

A number of materials capable of absorbing large amounts of water have been advocated as being beneficial in tree establishment. The more recent of these (polyacrylamide gels) are relatively stable in soil and can increase the water holding capacity of sandy soils in particular. For unirrigated tree planting in sandy soils this may be advantageous as more rainfall can be trapped in the treated soil. In finer textured soils this benefit is less obvious as these soils already have higher water holding capacities. Research on their use in soils for ornamental plantings, particularly in dry climates has generated variable results (Winkelman and Kendle, 1996). Craul (1999) suggests that these materials are of little benefit but further research as to their use in urban landscapes in arid and seasonally arid climates is warranted.

Once irrigation is used, the use of these materials becomes more vexed. If irrigation is well managed, they do not save irrigation water as an increase in WHC just means that more water has to be added to bring the soil to field capacity. They could however, extend the time interval between irrigations, especially in sandy soils. Even in this case, the evidence at present suggests that the potential benefits are small. As one example, a container study in the US demonstrated that seedlings in 8 L pots with gel lasted for 7 days before wilting while untreated pots lasted 6 days (Letey et al, 1992).

I tested a locally available product and found that 10 g of dry gel absorbed 1400 mL of water but in the process expanded to a volume of 1400 mL. The amount of this product that could be used in a planting hole is relatively small because large quantities will result in swelling of the backfill soil and can also reduce aeration in the backfill (effectively cause a waterlogging problem). Suggested application rates are in the range 1 – 6 g dry gel/L backfill (Handreck and Black, 2002). The material I tested, added to a 150 L backfill at 1 g/l would hold 21 L of water. While this may seem useful, it must be remembered that the gel granule is replacing a similar volume of soil that also has a water holding capacity. Only part of the water held in a gel granule can be counted as “extra” water. Using the data in table 3, for a tree with a 2 m crown diameter, this volume of water is only approximately 1 day’s worth in summer in Melbourne and less in Adelaide. It must also be remembered that these materials can only be of any benefit once the tree has made significant root exploration of the back fill soil.

Wetting agents

The use of wetting agents may be a simple way of improving the watering of trees. A wetting agent is a surfactant that effectively makes water “wetter”. By increasing the uniformity of uniform wetting and by overcoming hydrophobicity in soils and root balls these materials are probably more useful than we think. They are different to the water-absorbing gels in that there is no extra water holding capacity being added to the soil. Rather, one is intending to make sure that when water is added, it is absorbed into the soil rather than running off. Wetting agents have been used to improve plant performance in pastures and crops in sandy soils (Crabtree and Gilkes, 1999a, 1999b) and in container media (Blodgett, Beattie and White, 1995). There seems to be little research on their use in landscape media but I believe that they may have merit.

CONCLUSION

The trend to planting larger and larger trees in our streets and landscapes means that early water management becomes more and more critical to their success. Understanding the soil/plant/environment system is an important part of the essential task of matching plant water needs with water application. I don't see any "magic bullet" solutions available. Knowledge and care are still the most valuable tools you have available to you to use.

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