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NURSERY PRACTICES AND THE EFFECTIVENESS OF DIFFERENT CONTAINERS ON ROOT DEVELOPMENT

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Introduction

Trees can be very long-lived and the successful establishment of all trees in any given landscape requires a knowledge of their biology and also depends on a combination of important factors which include site assessment and analysis, plant selection, site preparation, planting techniques and post-planting management input. This is as true for trees being planted for amenity purposes as it is for trees in commercial plantations. Yet time put into appropriate cultivar selection, site analysis, site preparation and ongoing management can all be wasted if the quality of the container grown plant material is poor.

In Australia the vast proportion of nursery grown trees spend some part of their life containerised, usually in a rigid plastic pot of some type (Lawry & Gardner 2001). The challenge facing nursery growers producing trees is to not only optimise canopy growth but to ensure that the root and shoot system have been managed to ensure that they don't have a negative impact on long-term growth and even survival. Container production systems can be quite successful but nevertheless there still remain a number of very serious concerns about the quality of the root systems of many that are being produced by many container nurseries. This is despite a substantial body of research related to this issue and the many products and techniques that have been developed to improve root systems eg Harris (1967); Whitcomb (1988); Appleton (1995); Struve *et al* (1994); Arnold and MacDonald (1999).

This paper will briefly explore the nature of such containerised root distortions and the deleterious impact that they can have on the long-term health, vigour and stability of the tree once planted into the environment. It will then critically examine tree growing with reference to the role different containers can have on the production of quality root systems and will conclude with some practical advice regarding the evaluation of container grown trees for root defects.

Root system quality and landscape establishment

Unfortunately because trees are very long lived it can take years for problems of poor quality root systems to become apparent and often it isn't realised that the problem was poor nursery production practices which crippled the root system and doomed the tree at planting.

Foresters, arborists, various landscape managers and others who have witnessed the windthrow, lack of vigour or death of trees which can be attributed to container induced root distortions have all learned that a healthy root system is essential for successful tree establishment and long-term health.

The challenge to containerised tree growers is simply stated: produce container grown trees with a root system that has the potential to develop those architectural, engineering and biological characteristics approximating those of a natural root system because this ensures the tree has the best chance to become fully and successfully established. It is currently beyond question that poor root system quality at planting can result in trees subject to poor growth, windthrow, trunk breakage at ground level and the premature failure of plantings.

Major nursery-induced root defects

Root system defects in container grown trees can be traced to two elements in the nursery production system: the techniques used in the nursery to handle the plant at the propagation phase and the effect the containers have both on root growth and the subsequent root architecture.

Kinked roots usually occur when the struck cutting or seedling is pushed into a dibbled hole in the container growing medium. Unless this is done with extreme care it is likely to cause serious angular distortions in the main roots of 90° or more just below the level of the container medium. It is easy to understand how this can occur when you realise the length of a seedling's root system can be more than 20 times its height at the four leaf stage. Such kinking (known in SE Australia as J-rooting) can be the source of serious, major structural weakness at the trunk / root interface as the tree grows. In extreme cases J-roots can lead to the trunk of the tree lying in the soil a bit like a ball in a socket and the stem can simply snap off at this point a number of years after planting (Hitchmough 1994; Ford 1996).

Circling roots, which begin to circle in the nursery container, have the potential to girdle the trunk or major roots as the tree grows in the landscape. They occur most frequently in round, smooth sided (or almost smooth sided) containers with sloping sides but can be found in most container designs at varying frequencies particularly if trees are held in the container for too long. Such circling roots can girdle the trunk or other roots as they grow radially and lignify and restrict the flow of water and metabolites through the root-crown area. They have been clearly implicated in tree stress, decline and lack of stability (Whitcomb 1988). Trees may survive and grow with apparent vigour for a number of years before the effect of such root crippling becomes apparent. The consequences for the tree is that the resultant root system architecture can lead to it being unable to adequately anchor the tree in the ground. Such failures are potentially catastrophic.

Observation of a large range of different tree species in the landscape both here and overseas has revealed that the poor performance of many is a direct result of such kinked and circling roots**.** Unequivocally, kinked and circling roots can not only restrict the growth of trees but can be the cause of their death.

Production alternatives to improve tree root systems

There are a number of alternative production systems being put into commercial practice in Australian nurseries today which include physically pruning the roots at every potting on stage of the nursery production process (Clark 1996) and variations of container design (Moore 1998). Those variations include the use of internal ridges designed to guide roots down rather than around, channels to guide root growth to holes in the container walls where the roots are air pruned, the use of low profile containers, the use of chemical root pruning agents such as copper hydroxide infused paint and various combinations of the above.

THERE IS NO PRESCRIPTION AVAILABLE FOR AN IDEAL NURSERY PRODUCTION SYSTEM FOR TREES. IT DOES SEEM THOUGH, THAT A PRODUCTION SYSTEM WHICH NOT ONLY PREVENTS KINKING AND CIRCLING BUT ALSO STIMULATES THE DEVELOPMENT OF WELL

BRANCHED, FIBROUS ROOTS IS THE MOST DESIRABLE BECAUSE SUCH A ROOT SYSTEM CAN PROLIFERATE RAPIDLY INTO THE SURROUNDING SOIL AND PRESUMABLY ENHANCE TRANSPLANT SUCCESS (ARNOLD, 1994; WHITCOMB, 1984). COMMON SENSE SUGGESTS THAT THIS WOULD BE PARTICULARLY SO IN THE LESS FAVOURABLE ENVIRONMENT OF MANY URBAN SOILS (SMITH & MAY, 1997) WHERE WHITCOMB (1984) HAS SPECULATED THAT TREES WITH FEW LARGE ROOTS ARE FAR LESS SUCCESSFUL THAN THOSE WITH A LARGER NUMBER OF RELATIVELY SMALL ROOTS ARISING FROM THE ROOT STEM JUNCTION.

Reducing kinked roots

There are two potential solutions to the problem of root kinking (or J-roots). The first is to eliminate dibbling (where a hole is formed in the container medium and the germinated seedling or struck cutting is removed from its propagation environment and placed in the hole). If dibbling is unavoidable, careful root pruning before transplanting and the elimination of dibbling has been shown to be of benefit (Harris 1967), but even the most careful management of this might not guarantee the absence of j-roots.

An alternative is the direct seeding of the crop either into the final production container or an intermediate one. This technique does require an increased area for propagation, as well as a need for high quality seed and possibly increased culling of variable seedlings, nevertheless it simply eliminates any possibility of inducing severely kinked roots through inappropriate handling.

Reducing circling roots

There has been some work published detailing techniques to overcome circling roots of container grown trees prior to planting them out, including making vertical slices through the root ball, 'butterflying' the rootball or vigorously cutting off any apparently circling roots, (eg Flemer, 1982; Gouin, 1984) but such techniques are of doubtful value. Removing up to 90% of a tree's roots totally negates the advantages of growing trees in containers in the first place and is therefore a nonsense. Common sense dictates that the elimination of root distortions during the nursery production phase of a tree's life is the sensible approach and a number of alternatives are now available to the nursery industry.

Container design modifications

Internal ridges

There have been reports of ridges on container walls being used to minimise root circling and in this their use has some success (eg Warren & Blazich 1991; Appleton 1995) although their effect can be lost as more root mass builds up. Hughes (1994) argues that the standard Australian forestry tube (square containers with internal ridges and air pruning at the bottom) while reducing the incidence of circling roots, can still be problematic for further container growing because it has the effect of concentrating root tips at the bottom of the container which inhibits the development of lateral roots in the top 10 cm of the root system and leads to problems for further container growing.

Air pruning of roots

Another concept shown to have considerable potential are containers that allow roots to be air pruned by using openings in the sides or the base of containers. Root tips reaching such openings are dried out and stop growing. Such containers are designed to prevent the development of circling roots and have been shown to alter the growth and distribution of roots within the root ball (eg Whitcomb 1981; Arnold and MacDonald 1999). Instead of being concentrated around the sides and bottom of the container, roots in such containers are smaller in diameter and more evenly distributed throughout the rootball and develop a large number of root initials. This enables much new root growth once the tree is planted out. Many containers use this approach, examples available in Australia include SpringRing® containers, the RocketPot®, the Rootmaker® and the Lannen System. A number of commercial Australian tree producers have taken up this technology.

In a trial at Burnley, that compared the effect of an air pruning container (200 *mm* SpringRing®) with a standard 200 *mm* standard rigid plastic container on the root system quality of a range of native landscape trees, the trees were grown on for nine months in the two production container types and then planted out. They were then dug up 8 months after planting out and root quality assessed by examining the root systems at the outer edge of the production container rootball.

Table 1. *Effect of production container on root quality in landscape trees*

Species	**Container type**	**Number of circling roots**	**Number of emerged laterals**
Allocasuarina verticillata	200mm rigid plastic	22.4	25.8
Allocasuarina verticillata	200 mm Spring Ring	0.0	74.6
Casuarina cunninghamiana	200mm rigid plastic	21.8	123.8
Casuarina cunninghamiana	200 mm Spring Ring	1.4	132.8
Callistemon viminalis 'King's Park Special'	200mm rigid plastic	14.2	141.8
Callistemon viminalis 'King's Park Special'	200 mm Spring Ring	0.2	196.0
Eucalyptus leucoxylon	200mm rigid plastic	6.6	75.2
Eucalyptus leucoxylon	200 mm Spring Ring	0.2	161.6
Corymbia (syn. Eucalyptus) maculata	200mm rigid plastic	14.0	38.0
Corymbia (syn. Eucalyptus maculata)	200 mm Spring Ring	0.2	106.8
Lophostemon confertus	200mm rigid plastic	28.7	101.5
Lophostemon confertus	200 mm Spring Ring	1.3	199.3
Waterhousea floribunda	200mm rigid plastic	8.4	22.2
Waterhousea floribunda	200 mm Spring Ring	0.0	33.2

Moore (unpublished data Generally, the trees grown in the air-pruning Spring Ring® container had superior quality root systems, both in terms of the number of circling roots and the number of lateral emerging into the surrounding soil.

Chemical pruning of roots

A different approach to the reduction of circling roots that is also being used by commercial Australian tree growers, involves the use of copper compounds to chemically prune the roots of container grown plants. The use of copper compounds to inhibit root tip growth has been reported since early 70s (Furuta *et al*, 1972). Several commercial formulations have been marketed with SpinOut® (Griffin Corp.) perhaps the best known. SpinOut® is copper hydroxide infused latex paint that is applied to the interior surfaces of the container where it acts as a growth regulator. In effect root tip growth is inhibited, which stimulates branching and ultimately results in a fibrous root system (eg Struve and Rhodus, 1990).

Recent research at Burnley has shown that SpinOut® can reduce circling roots and improve root system quality, but that it is not a perfect solution to the problem. Table 2 shows the results of an experiment with *Corymbia (syn. Eucalyptus) maculata* (Spotted Gum) seedlings grown in 50mm tubes, 50mm tubes coated with SpinOut® and the air pruning Rootmaker® pots.

Table 2. The effect of propagation container on a number of seedling quality parameters in *Corymbia maculata*

Seedling quality parameter	50 mm tube	50mm tube with SpinOut®	ROOTMAKER®
Height (mm)	238	202	216
Number of roots emerged one week after potting	30.6	71.4	281
Number of lateral roots from tube after 6 months	0.9	9.4	10.8
Number of circling roots / plant	6.8	3.9	2.6
% plants with circling roots	93	80	40

(Moore, unpublished data)

In this experiment, the propagation containers were direct seeded and the resultant seedlings grown for 18 weeks before potting on into 200 *mm* production containers. The one week data was for seedlings examined one week after potting. All the other data was for seedlings grown on for six months. The circling roots were assessed at the outer edge of the propagation containers. It's clear that both the copper treatment and the air-pruning Rootmaker ® modified the root systems of the seedlings but these data suggest that at the tubestock stage at least, root circling problems are difficult to entirely overcome.

Without undertaking an exhaustive analysis of the data gathered it is apparent that both chemical pruning and air pruning do have an effect on the number of new roots emerging from the rootball. Interestingly, the implication from this data is that the Rootmaker container caused more root initials to develop than the either the standard tube or the tube coated with Spin Out®.

The data gathered relating to the production/propagation container interface at 8 months is also interesting in that clearly both Rootmakers and Spin Out® achieved increased lateral root development. The relationship between the numbers of emerged roots at 7 days compared with the number of lateral roots developed at 8 months is not yet clear though.

Evaluating trees for root system defects.

Two points need highlighting:

1. *Kinked roots and girdling roots have unequivocally been identified as a cause of tree stress, decline and death.*
2. *There have been no studies which have identified how severe the kinking or circling has to be before a tree's root system has been crippled to the point where the long-term health and performance of the tree will be compromised.*

The obvious consequence of this is that tree root systems *must* be inspected to detect any serious deformities. A visual inspection of the rootball surface *is not* sufficient because serious defects can and do occur in different zones within the rootball. It will be necessary to wash the potting mix from the roots.

The following general guidelines are presented to aid the assessing the root systems of container grown trees, regardless of species, size or intended landscape function. They are based on the work of Harris *et al* (1999, pp. 614-615) and Gilman (1997, pp. 44-47). All trees (or a representative sample) should be carefully inspected.

A lot can be learned by inspecting the tree while it is still in its container and then looking at the periphery of the rootball. The reality though, is that a number of serious deformities may be out of sight within the rootball and it will be necessary to remove some or all of the container medium.

The first thing to do is to check whether there are any obvious kinked or circling roots at the surface and that there are no roots sticking up above the potting mix. Having done that, ensure the bottom of the container won't move (hold it between your feet perhaps) then hold on to the trunk of the tree about two thirds up the trunk and move it backwards and forwards a couple of times. If the trunk wobbles in the container medium before it bends where you are pushing and pulling it is likely that there are either kinked or circling roots already negatively affecting the tree's root architecture.

Unless the tree is very advanced, the root system should be able to be picked up by the trunk without any apparent root movement and should be sufficiently developed to hold the root ball together when its removed from the container.

If it is staked, untie the tree from its stake (when you do, the trunk shouldn't lean so much as to touch the rim of the container), then remove the tree from the container and examine the roots as follows:

No large circling roots should be visible on the outside of the root ball and there should be no circling mat of roots at the bottom. It is not possible to give an acceptable diameter for these roots; it depends on the size of the rootball and the complex biology of the species grown. It would be best if they were absent. Harris *et al* (1999) recommends circling roots be no larger than 6 *mm* in diameter.

Then lay the rootball onto its side and with a sufficiently vigorous jet of water, carefully expose the roots within 5 - 6 *cm* of the trunk to a depth of about 7-8 c*m* below the root attached closest to the trunk. Both the trunk and main roots ***must*** be free of kinks and circling roots in this part of the rootball, if they're not, the tree has severe root defects.

If the above inspections reveal no faults then the *complete removal* of the container medium from the entire root balls of least two trees (Harris *et al* 1999 recommends no more than 2% of the total number of trees) is required to inspect their centres. Again, both the trunk and main roots ***must*** be free of kinks and circling roots in this part of the rootball, if they are present, the tree has severe root defects. (This is a destructive sampling as it is likely the tree will die even if the potting mix is replaced and carefully watered).

These can only be general guidelines because there is a paucity of basic scientific research regarding the effect various container production systems have on the root growth and subsequent landscape establishment of different tree species. The work simply has not been done. What is beyond doubt though, is that the unique environment in plant containers limits the time any plant can spend in a specific container before it must be planted, potted up to a larger container, subject to expert pruning of both roots and stems or simply thrown away.

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