GETTING TO THE ROOTS OF THE PROBLEM

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INTRODUCTION

A well formed root system is an essential prerequisite for the growth and development of a vigorous tree and the achievement of a full life-span (5). There has been a long history of concern about the malformation of root systems by propagation and planting (or transplanting) techniques (7). Distortions of the root system may be so severe that poor growth, toppling or even death may result (4).

Harris (5) identifies two types of root defects:

1) kinked roots in which the major roots are bent, and
2) circling or girdled roots in which the roots circle around the stem or other roots.

The degree of root deformation is affected by nursery practice, container design, planting method and the site (6). Such factors can cause the development of abnormal root systems in container-grown plants. Indeed the root system of container-grown plants may never develop the same structure as the "normal" system of direct sown plants.

The root formation of plants grown from cuttings is rarely the same as the same plants grown as seedlings. Similarly, nursery production techniques usually cause malformation (3). After planting, the distortions of the root system may persist for many years (2), although the degree of distortion may decrease with time (6). Although distortions usually reduce growth and may kill the plant, it is surprising that a relatively small proportion of free roots may be sufficient to sustain the plant (5).

In this study, field observations of planted trees toppling over have led to a review of planting and propagation practices. Subsequent experiments examined the relationship between the root and shoot development and the size of the container in which the plants were grown. There are implications for the growing of native plants, especially when the situations in which the trees are to be planted, are considered.

MATERIALS AND METHODS

The first part of this study simply consisted of observations on the toppling of 8-year-old *Eucalyptus regnans* trees growing at Toolangi, Victoria. Some 1317 trees have been

planted in this Victorian Forest Commission experimental plantation. These trees were approximately 20 to 25m tall with a diameter at breast height of about 25 to 35cm. The root systems of 10 recently fallen or loose trees were excavated and the structures of the root systems determined. Later, sections of the root system were photographed.

In the second part of the study, random samples were taken of the seedlings growing in the production nursery at the V.C.A.H. — Burnley. The seedlings were removed from their pots and the roots examined. Deformities in the root systems were identified and the causes determined where possible. The proportion of "normal" to deformed root systems among the seedlings was also recorded.

The third aspect of this work involved the raising of *Eucalyptus camaldulensis* from seed; 100 seedlings were grown in 5cm pots, 40 in 7.5cm pots, and 30 in 15cm pots. Each week, from week 4 to week 9 after germination, seedlings were transferred from the 5cm pots to the 15cm pots. At the end of the 10 week experimental period, the height, leaf number, fresh weight, and dry weight of the seedlings were recorded. Each week the progress of roots in the 5cm pots was investigated by removing the seedlings, and observing how far the roots had grown into the pots.

RESULTS

Results from the first phase of the study showed (Table 1) that the proportion of fallen trees in the plantation was increasing. Examinations of trees that had fallen in 1982, 1983, and 1984 revealed that in every case root systems were seriously deformed (Figure 1). The deformities in each tree were responsible for a weakening of the trunk, at or below the soil surface (Figure 2), which caused the plant to fall.

Table 1. Fallen trees at Toolangi, Victoria. (The plantation was established with 1317 trees in 1976).

Year	Fallen Trees
1976	0
1979	32
1984	77

In the second part of the study samples taken at random from the container-grown seedlings revealed that several different causes of root deformity could be identified (Table 2). These correlated with different phases of the plant production process. The number of plants with deformed root systems was unexpectedly high (Table 3).

Figure 1. Deformed root system on a fallen tree at Toolangi.

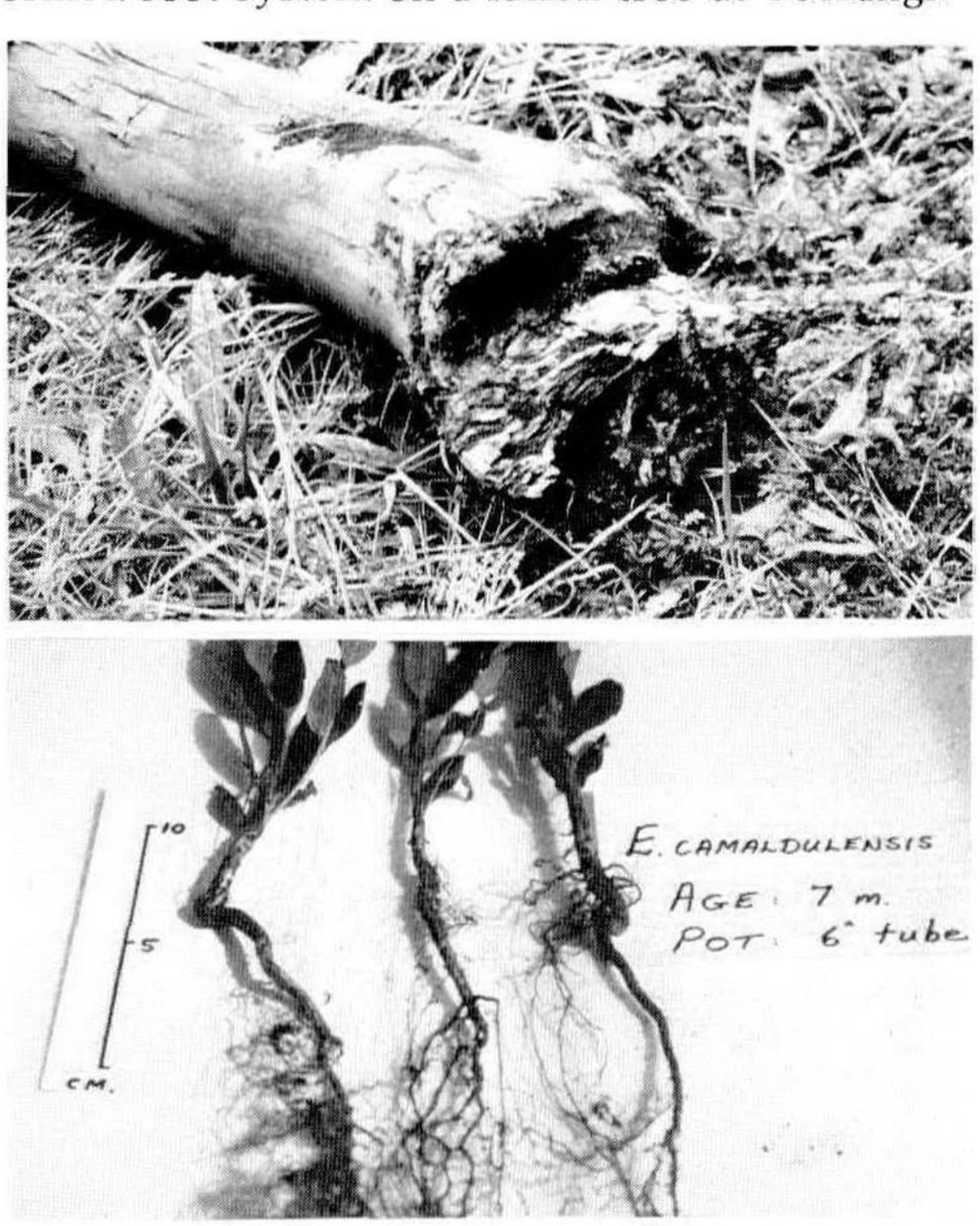

Figure 2. Examples of deformed root systems. *Above*: From a fallen tree at Toolangi. *Below*: From container-grown seedlings.

Table 2. Causes of root deformity due to propagation and planting procedures.

Procedure	Aspect of Procedure Causing Deformity	Kinking	Circling
Propagation	1. Depth of Germination Tray	✓	
	2. Pot (a) shape		✓
	(b) diameter		✓
	(c) depth	✓	✓
	3. Pricking out	✓	
	4. Potting on	✓	✓
Planting	1. Hole (a) shape		✓
	(b) diameter		✓
	(c) depth	✓	✓
	2. Twisting as planting		✓
	3. Depth of planting	✓	

Table 3. Deformities in the root systems of seedling samples, taken at random, at the VCAH nursery.

Species	Sample size	Roots % Normal	Roots % Deformed	Major cause of Deformity	Size of pots
Eucalyptus camaldulensis	20	10	90	Pricking Out	15cm tube
	5	20	80	Pricking Out	7cm pot
E. maculata	10	20	80	Pricking Out	15cm pot
E. melliodora	10	30	70	Pot shape	7cm pot
E. pauciflora	5	0	100	Pricking/Pot shape	15cm pot
E. leucoxylon	5	0	100	Pricking/pot shape	7cm pot
Melaleuca ericifolia	5	60	40	Pricking/Tray	15cm tube
	5	0	100	Pot size & shape	7cm pot
Leptospermum phylicoides	5	40	60	Pricking Out	7cm pot
Bursaria spinosa	5	100	0	—	7cm pot

The final part of the study revealed that plants which were grown in larger containers grew more rapidly (Figure 3). The increases were real in that plant dry weights increased substantially (Figure 4). Transplanting of seedlings from small pots into larger ones improved growth, but growth was still significantly less than for seedlings sown directly into large containers.

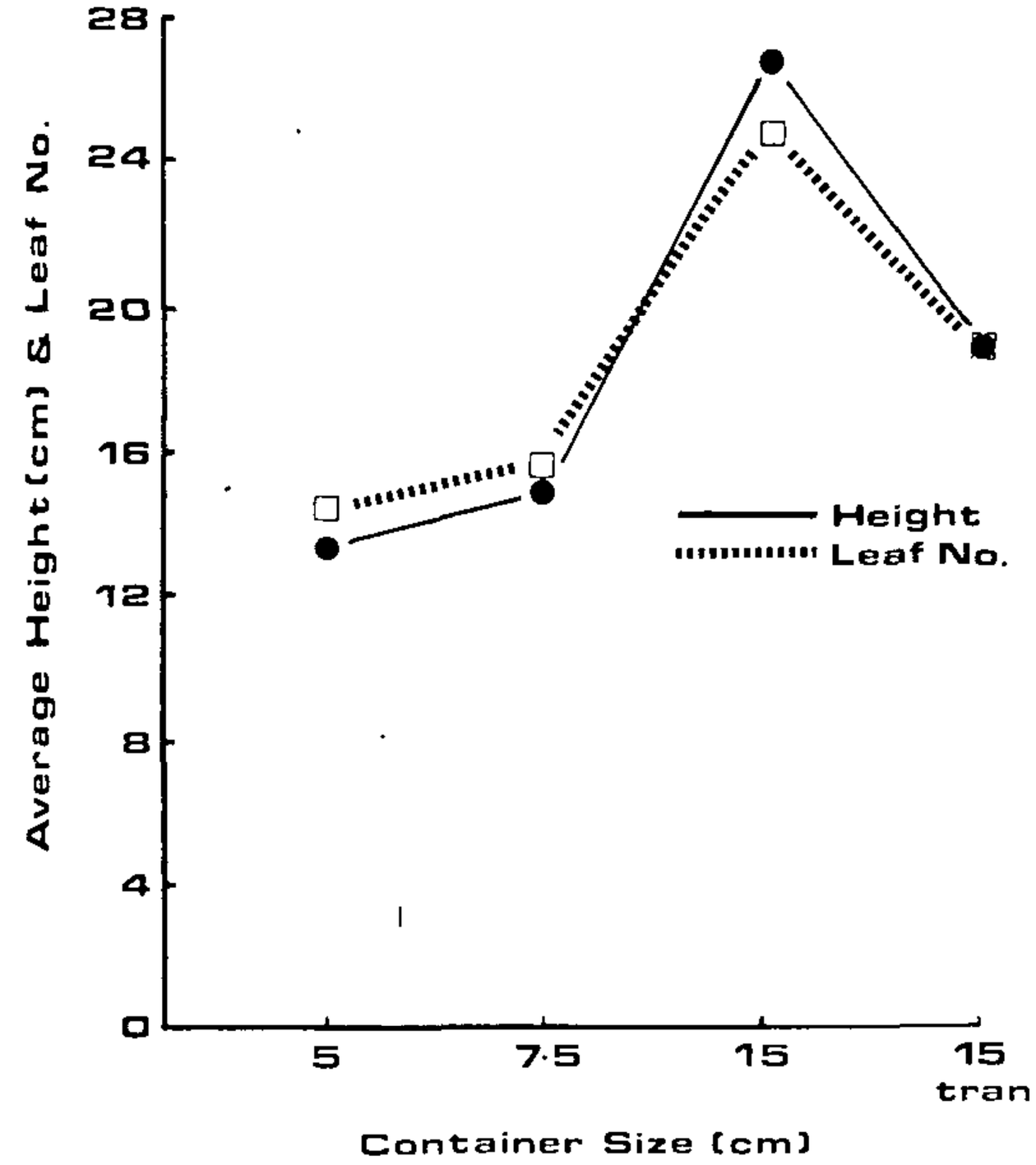

Figure 3. Average height and leaf number vs. container size.

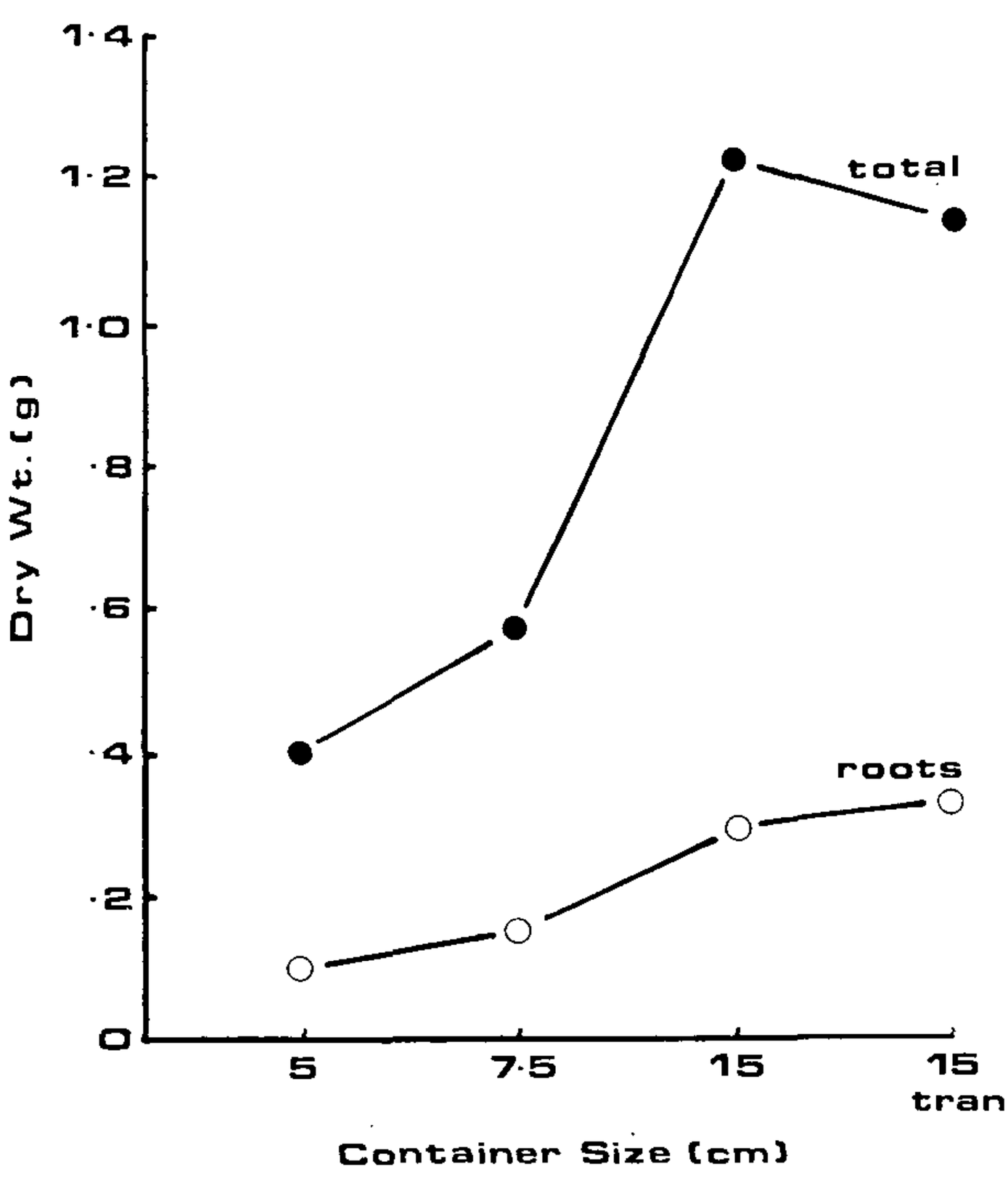

Figure 4. Average dry weight of whole seedlings and of root systems vs. container size.

DISCUSSION

It is comparatively rare that the demise of trees can be traced back with any certainty to poor plant propagation or planting technique. This can be done at Toolangi, however, where the circling of roots has either girdled the plants own stem or caused the development of major lateral roots on one side only. The causes of these problems may be two-fold:

1) The use of pot-bound seedlings where the root systems were already circling within the pot. The seedlings were planted without any correction of these problems.
2) The planting of seedlings with larger roots which, as they were placed in the holes, the plants were twisted so that all the roots could be accommodated in the small holes.

The 8-year-old trees at Toolangi were substantial plants, and the high incidence of fallen trees represents a dangerous situation. The root systems of some standing trees were so weak that the trees could be shaken by hand. It is likely that the proportion of fallen trees in the plantation will continue to increase in the next few years.

It is also worth noting that trees with deformed root systems, especially those which are circling, may actually grow better than "normal" trees in the initial years of growth. This is because the roots are starved, partially or totally of photosynthate, and so the foliage, and stems, above ground may be healthier and bigger in appearance. Eventually, however, as the restrictions become more severe the health and vigour of an affected tree decline (8).

Growth of plants of native genera in containers has always given some cause for concern. This has been especially true for eucalypts, which have very long tap roots as seedlings. The tap root may be four times as long as the stem in this early seedling stage. The tap roots are important for the establishment of the young seedlings although they may be lost after 8 to 10 years as the tree matures (1). This means that there are likely to be problems when seedlings are germinated in flat trays, which have a depth of about 5 cm, or when seedlings are "pricked out". Accordingly plants should not be left in trays for long after germination and should be planted into the largest pot practicable.

The choice of propagation strategies is not easy. Large pots take more space and space is costly. This extra cost, however, may be more than offset by greatly reduced handling and growing times. In this study, saleable eucalypts were produced within three months. It would seem that greater attention to the relationship between plant and pot size may pay divi-

dends. Furthermore, the use of container-grown stock may be inappropriate for some situations. The use of direct-seeding techniques might be better in forests or salt-affected rural areas where deep-rooted trees are required.

Propagation which involves "pricking out" or re-potting every few weeks would appear to increase the risks of root deformity, especially "kinking". This necessitates great care by operators and some pruning of the root system to reduce the risk of deformity would seem wise (3). As far as the development of a healthy root system is concerned it would seem that the less the interference the better the system. This means larger pots and fewer re-pottings. The economics of this sort of system are not simple — there are both gains and losses.

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