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The Evolution of Container Design©

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INTRODUCTION

While plants have been grown in containers for many thousands of years, formal design of plant containers is more recent. The most rapid developments in container design occurred in association with the rapid development of container production that occurred after WW II. Changes in nursery practice, increased research into plant growth, and plastics manufacturing technology all contributed to the changes in design that have occurred in the past 50 years. In this paper, most emphasis will be placed on containers for woody plant production because of the well-documented deleterious effects that poor practice can have on root system quality in trees and shrubs.

WHAT IS CONTAINER DESIGN?

In order to trace an evolution of container design in nursery plant production, we have to initially define what we mean by design. Design is generally held to involve a deliberation of thought in order to bring about a particular end or function. If one takes the view that container design occurs when a set of objectives are set out, and a process is undertaken to ensure that these objectives are met before the container is made, then container design, especially for woody plants, can probably be dated to relatively recently.

In any modern container design process, it seems to me that several criteria should be imposed. These are: Does the container grow the plant in such a way that there is no impairment of growth, either in the nursery or subsequently; can the container be manufactured; is the cost of the container low enough that it can be used economically; does the design allow for easy uptake by the nursery industry? Experience and observation would suggest that unless all of these criteria are met, uptake is unlikely irrespective of how good the container is. Unfortunately, the first of these criteria has often not been taken into consideration when the design process has been undertaken.

EARLY USE OF CONTAINERS FOR TREES

The Egyptians used containers to transport trees from Sudan to Egypt around 4000 years ago (Baker, 1954). These containers were carved out of stone. It is likely that this technology was used in other ancient cultures around the Mediterranean, either for transport or for plant culture but it is likely that all these applications were applied to plants dug up from field nurseries or from the wild. Ceramic containers were almost certainly also used in these regions and in Asia and have been in continuous use for thousands of years. Ceramic containers have also been the mainstay of the pot-plant industry until relatively recently. Tree growers have used ceramic pots but they are not at all satisfactory for that purpose, causing serious root system faults.

INFLUENCES ON THE WOODY PLANT NURSERY INDUSTRY

Many factors led to the development of the container nursery industry we know today. The automobile, the growth of nursery businesses in warm climates such as southern U.S.A. and Australia, and the growth of retail nurseries all made containers an attractive proposition for growers. Texts written in the U.S.A. (Davidson et al., 1988; Whitcomb, 1987) all suggest that major growth in the container industry occurred following WWII but there must have been a fledgling industry prior to that. There is evidence to suggest that in Australia, a significant container industry existed much earlier than this (Brunning, 1934).

THE POT PLANT INDUSTRY

Whitcomb (1987) observes that the container industry in the U.S.A. took many cues from the pre-existing pot-plant industry. The greenhouse production of potted plants has a very long history. While the techniques for growing plants in containers for their entire life were well established by greenhouse growers, this industry offered little to the woody plant industry in terms of container design. Until recently, the typical plant pot was made of terracotta and was conical in shape (to allow stacking, removal from moulds and for easy removal of the root ball). This design was apparently not questioned by the woody plant growers who adopted it. For instance, in their text "Plant Propagation", Mahlstede and Haber (1957) do not discuss container choice at all. The only containers illustrated in this book are small diameter terracotta pots being used for the culture of small plants. It seems to be a topic not worth discussing by the propagator at the time, possibly because there was no opportunity for choice. At this time growers were also using tin cans and tar paper to fashion containers (Davidson et al., 1988).

However, when woody plants were grown in these containers, root deformities were common. For instance, Brunning (1934) recommends cutting curled roots when planting out of pots. Harris (1967) documents the very common problem of deformed roots at the liner (tubestock) stage having severe impact on subsequent plant performance and survival. Harris et al. (1971, 1971b) carried out research to show how this problem could be minimized by managing plants better (root pruning and timing of production) but there was no attempt to modify the containers by formal design processes. In this paper they stated that they were "not aware of any other literature related to this aspect of liner production".

PLASTICS

In many respects, the real opportunities for container design did not appear until the advent of cheap thermoplastics such as polyethylene. This plastic was used either to make film that could be used to manufacture planter bags or was injection moulded to make rigid pots. By the 1960s, bags were commonly used for nursery stock production (Boden et al., 1969) and rigid pots became more common from the early 1970s. The first rigid plastic pots simply mimicked the shape of terra cotta pots or used moulds for buckets or garbage bins. These pots were most unsatisfactory as they frequently caused root girdling (Whitcomb, 1988). However, plastic ultimately allowed designs that started to take into account the biology of the root system. Before this work could happen, a better understanding of tree root behaviour was needed.

MILESTONES IN ROOT DEVELOPMENT RESEARCH

Many researchers have contributed to our understanding of tree and shrub root growth in containers. The following discussion highlights some of the major steps in this process. Harris (1967) identified the development of girdling roots at the container wall as a major problem in tubestock (liner) production in ornamentals. This was confirmed in forestry stock by Tinus et al. (1974). The phenomenon of air-pruning of taproots in bottomless containers was demonstrated in 1969 (Whitcomb, 1987). The effect of this on the development of a more branched root system was described by Whitcomb (1987), as was the observation that excessively deep containers did not allow adequate lateral development.

Tinus et al. (1974) describe containers with internal ridges to reduce the formation of girdling roots. The use of air-pruning slots in container walls to overcome the formation of girdling roots is first described by Whitcomb (1987). This technique was incorporated into Whitcomb's Rootmaker® and Rootbuilder® systems for tree production. The latter technology was adopted in Australia as the basis of the Spring Ring® design in the very early 1990s. A similar system is the Accellerator® (Appleton, 1998). Other container manufacturers [e.g., Lannen (Lannen Plant Systems, 2002)] have also incorporated lateral air-pruning into some of their tree propagation systems.

Chemical management (usually with copper compounds) of root development was first described by Furuta et al. (1972). After extensive research on the effects of copper on root development in containers (e.g., Arnold and Struve, 1989), commercial formulations of copper compounds in latex paint carriers have been marketed and some container manufacturers are selling containers that are pretreated (Lerio Corp., 2002). While this system is attractive because it allows the grower to continue to use existing container systems, research with some native Australian trees species (Moore, 2002) suggests that copper treatment of pot walls is not a quick fix solution to poor pot design.

Several authors have worked on container dimensions and their effects on plant growth. Containers for direct landscape planting tend to be relatively deep to provide some stress tolerance (Tinus et al., 1974; MacDonald, 1986). On the other hand, containers for tubestock that is to be potted up for further growing should be shallower than this. Whitcomb (1987) advocated that containers for tubestock (liners) should have a width to height ratio of about 1 : 2. His Rootmaker® container was designed on that basis. Hughes (1994) argues that the standard Australian forestry tube (W : H ratio 1 : 3) does not produce an ideal seedling for further container growing because of root tips ending up at the bottom of the container rather than distributed evenly over the outside of the rootball.

A related issue is that of the correct dimensions for containers used for growing on larger-sized specimens. Early pot designs tended to gain extra volume by increasing both container diameter and depth. In most soils, however, very deep containers will result in roots being placed into parts of the soil where oxygen is limiting for root development. Milbocker (1991) advocated and designed the "low-profile" container with an optimum depth of 200 to 300 mm. His ideas have been incorporated by a number of manufacturers.

THE AUSTRALIAN EXPERIENCE—A FOOTNOTE

The majority of the published research on container design comes from the U.S.A. Australian nurseries provide an interesting counterpoint to this work, suggesting a long history of container tree production with high quality outcomes. Most of this history is not based on published research and thus does not appear in the literature.

Much of the Australian flora is difficult to transplant and a consequence of this must have been that early cultivation of Australian plants used containers for the whole production process. The techniques used are not well documented but bamboo cut into cylinders was an early system used in state-run forestry nurseries in South Australia and Victoria in the mid 1870s. What is claimed to be the first forestry nursery in Australia was set up in South Australia and bamboo tubes were direct seeded with forestry plantation tree species (Lewis, 1975). William Curnow is credited with this approach but it is unlikely that the idea was his. One suspects that this practice evolved in Asia but how the technology transfer occurred is unrecorded.

The bamboo tube evolved into the rolled veneer "tube" (approximately 25 mm diameter and 150 mm deep) used extensively throughout Australia through much of the 20th Century. In fact this was a very good system for growing tree seedlings being deep, straight walled, and capable of air pruning the taproot. Cost forced the replacement of this system in the 1970s but the plastic container designed to replace it (the Victorian Forestry Tube), while easier to use and hence cheaper, was not as good and its sloping sides induced a higher level of root girdling than occurred in the veneer tube. Subsequent design modifications have seen internal ridging and lateral air pruning slots to help overcome these problems.

CONCLUSIONS

Container design for woody plants has undergone great changes in the past four decades. While many of the root system faults that early containers caused are now seen less frequently, there is still room for improved performance. Ideally, container designs should air-prune tap roots and eliminate girdling roots. The dimensions of the container should reflect the purpose for which the plant is being grown. There are still areas where research is needed to better understand the development of good quality woody plant root systems in containers.

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