INFLUENCE OF PLANTER SHAPES ON LANDSCAPE PERFORMANCE OF TREES IN ARID REGIONS

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Abstract

A research study was conducted to evaluate the effects of various container designs on growth and root deformation of Eucalyptus viminalis. Eucalyptus was selected for the study because of its ability to produce deep roots and its acceptability in landscaping industry of all Gulf Cooperation Council countries. The experiment was carried out over two years. In the first year, three-month-old bare root seedlings of E. viminalis were transplanted into three different containers, namely, Root trainers, spring rings and conventional containers. After a period of one-year growth, a subset of plants from each treatment lot was destructively harvested to determine the growth parameters, shoot, and dry mass weight and root deformation. At the beginning of the second year, the remaining plants in the containers were transplanted into open field to study the landscape performance of container-grown plants. For the plants grown in containers, there were no significant differences noticed on shoot characteristics among the containers. The poorest root architecture was observed in conventional pots; whereas, spring rings and root trainers reduced the percentage of deformed root mass. When the plants were transplanted to an arid landscape, plant height, and dry biomass did not significantly differ between the treatments. However, the plants grown in root trainers produced largest roots, well-distributed in the soil and detected less deformed roots than the other containers. The effect of the spring rings on plants grown in the landscape was obvious visually during research period in the short-term, but was not apparent from growth quantification. To obtain quality tree seedlings to support the horticultural industry, it is recommended to continue the application of R&D on container and plant relation.

Key words: *containers, eucalyptus viminalis, post transplanting, roots, arid environment*

1. INTRODUCTION

The greenery and beautification of Kuwait and other Gulf Cooperation Council countries demands a huge quantity of diversified quality planting materials. To achieve the greenery plan of Kuwait, suitable plants, as well as the best possible production technologies for the optimization of greenery enhancement should be developed (Bhat 1997, Taha et al. 1988). Moreover, with the introduction of indoor and miniature gardens, plant-specific types of containers are essential for the proper growth of plants. The landscape architects and nurserymen use container-grown plants to allow year-round planting to achieve project demands. Hence, containers in different designs and sizes are required for the production of seedlings to meet the immediate requirements. Plants grown in conventional containers for longer period of time often result in deformed root system that grow along the sides or the bottom of the root ball (Gilman et al. 2003). The research studies showed that the container design affects post-transplant growth of several species (Arnold & McDonald 2006, Gilman 2001). Development of management strategies that potentially promote rapid post-transplant root growth is another decisive factor for successful seedling establishment. Preventing the development of a few dominant roots must be the ultimate factor in designing improved containers, thereby, producing a fibrous root system on all sides that hold the root ball together (Mullan & White 2002). Since the roots were deformed, the transplanting stress of the conventional planters grown seedlings when compared to the root trainer-grown seedlings could be more and adversely affecting their survival and growth. These deformed root systems can contribute to instability, reduced shoot growth, tree decline and mortality (Ortega et al. 2001, 2006). Since the growth and establishment of out planted plants would depend directly on the ability of the root system to rapidly produce, the initial development of shoot and root morphology is critical (Paz 2003, Tsakaldimi et al. 2005). The longevity of individual

planter-grown trees depends on planter volume, dimensions, and the planter shape (Nesmith & Duval, 1998). A study by Ngulube (1989) in *Eucalyptus camaldulensis* seedlings observed an increase in growth with planting tube size.

A delay in transplanting from a conventional container to the landscape increases the chance of developing vulnerable root shape. Harris (1992) described that mechanical remediation of root malformation at transplanting can cause transplanting shock during field establishment. Similarly, low quality mechanical practices also may disrupt management objectives and cause unplanned maintenance expenses in landscape projects. Gilman et al (2010) introduced root shaving as a rent method of correcting root malformations. A number of alternative container types have been designed to reduce the incidence of deformed roots (Gilman et al. 2010). The designs of these specialized containers are based on the mechanisms of air root pruning, mechanical deflection, chemicals to control root growth, bottomless containers or nonwoven fabrics (Gilman et al. 2003; Marshal & Gilman 1998). Research studies (Gilman et al. 2003; Marshal & Gilman 1998; Tsakaldimi et al. 2005; Tsakalidimi & Gantsas 2006) observed that these modern containers can improve root architecture and achieve long-term establishment of plants. However, the study on the effect of container design on dry region is meagre.

This study evaluated the effectiveness of three types of containers on plant growth and root architecture of *Eucalyptus viminalis*. To provide further insight on the effect of container designs on landscape performance at a desert environment, evaluation of plant growth after transplanting in the field was also studied. The results from this research may help to improve practices of landscape engineers and nursery professionals.

2. MATERIALS AND METHODS

The study was conducted at the Waterfront experimental station of the Kuwait Institute for Scientific Research (KISR) located in Salmiya, Kuwait. The site is located at the northwestern end of the Arabian Peninsula between latitudes 28°30'and 30°5' North and longitudes 46°33' and 48°30' East. *Eucalyptus viminalis* seeds purchased from a commercial nursery were germinated in plug trays with same size and substrate composition. The plants were irrigated manually to maintain water content of the containers at near 100% of water holding capacity.

Three months after germination, the seedlings were transplanted into treatment containers filled with container mixture. The container medium consisted of 3:1:1:1(v/v) mixture of agricultural soil, sphagnum peat moss, perlite, and organic manure. Plants grown in conventional nursery plastic pots (smooth-sided round container of 4.5 x 9 x 3 cm) were compared with root trainers (a square container with eight vertical interior groves of 4 x 10 x 3 cm), and spring rings (a container made up of closed inward pointing cones and open ended outward pointing cones with a plastic net bottom of size 3.5 x 10 x 3.5 cm). All the containers were made of plastic. The experiment was laid out in a randomized design with three treatments (ten plants per treatment) and five replications. The entire experimental block consisted of three treatments giving a total of 50 plant population per treatment. Every week, each container was turned 90^{o}, so that the light levels around each plant were relatively even. Mineral fertilizer 19 N: 19 P_2O_5: 19 K_2O was used throughout the growing period.

At the end of the growing season, plant growth and root morphology were determined for fifteen plants per block, making a total of 25 plants per treatment. The plants were subjected to destructive harvesting and the substrates were removed by cleaning. Fine sieves were used to prevent any loss of root biomass. Shoot height from the soil level to the tip and the root lengths were measured. For each plant, deformed roots, nondeformed roots and above ground biomass were oven dried separately (104 C) for 48 h, and then dry weights were recorded. The percentage of deformed root mass relative to the entire root mass was used as the determinate of root system quality where low deformed percentage indicated a high quality root system.

At the beginning of the second year, the remaining five plants from the treatments were transplanted into an open field with an objective to determine the landscape performance of the container plants.

The planting of the seedlings was done in 50 x 50 x 50 cm sized pits in the field filled with a medium of 1:1:1(v/v) mixture of agricultural soil, sphagnum peat moss, and organic manure. The experiment design was a randomized block design with three treatments (five plants per treatment) and five replications. They were planted at a spacing of 3 x 3 m. Weeding around the tree basin was done to keep the experimental area clean and reduce pest and disease incidents. Data regarding the growth and root morphology were determined at the end of the growing season. Destructive harvesting was done for recording the root parameters. All the plants were carefully dug up from the field, and the soil particles were washed. Fine sieves were used to prevent any loss of root biomass.

Data from the container grown plants and the plants from the field study were subject to statistical analysis with the Statistical Analysis System (SAS Institute Inc., Cary, NC) package. The method of least significant difference (LSD) was performed to determine treatment differences.

3. RESULTS AND DISCUSSION

3.1. Container Design-Seedling Establishment

Subjective seedling quality was very good throughout the growing season. Shoot and total biomass were less responsive to container design, but the plant height, root length, and root biomass and percentage of deformed roots varied significantly between the container treatments (Table 1). The plants grown in conventional planters and spring rings were significantly taller than plants grown in root trainers. The actual mechanism of the difference in plant height among different containers in response to root restriction is still unclear. It may be due to the nutrient distribution in growth media in different containers. Initial results from a study conducted by ATREE (2004) revealed that the tree seedlings raised in poly bags were taller than those from root trainers.

Parameters	Conventional Pots	Root Trainers	Spring Rings
Plant height (m)	85.83a	75.17b	84.90a
Shoot dry weight (g)	5.97(NS)	5.10(NS)	6.11(NS)
Root length (cm)	14.80c	21.40a	19.20b
Root dry weight (g)	1.60b	2.28a	1.76b
Total biomass dry weight (g)	7.57(NS)	7.38(NS)	7.87(NS)
Deformed roots (%)	47.8a	39.3b	40.1b

Table 1. Effect of Different Containers on Shoot and Root Growth (sample size 25)

The means within same row followed by different letters are significantly differed from each other using LSD, NS indicates nonsignificant at (P = 0.05).

Shoot dry weight was unaffected by the container design at the end of the first growing season. The highest root biomass was observed in plants grown in root trainers; whereas, no differences were observed among plants grown in conventional containers and spring rings. This morphological difference may be due to the environmental changes or restrictions that occurred during the research period. This can be attributed to the moderate plant stress associated with new root regeneration. Moreover, spring ring containers are designed to introduce air into substrate through both container walls and bottom net; whereas, the root trainers are air-opened through bottom. This allows more water to evaporate from the substrate periphery as reported by Ortega et al (2006). Krizek and Dubik (1987) supported this finding by stating that in spring rings under both water and root restrictions, the total plant dry matter accumulation greatly increased. The positive effect of air pruning on root system architecture was also reported by Moore (2001) for Australian tree species grown in spring rings.

Marler and Willis (1996) reported that air root pruning containers produced more fibrous root system than conventional containers. There was no marked significant variation in the total top biomass, which clearly revealed that the shoot growth was not affected by the differences in containers. Root length varied significantly among treatments, with plants grown in trainers providing the longest roots. Root length was influenced by container depth; therefore, it was not surprising that root trainers gave the highest value, since self pruning took place in spring rings. Root dry weights were significantly higher in root trainers than other treatments. Arnold (1996) found that the type of nursery planter can have a dramatic impact on root morphology of container-grown plants. Also, could have been due to the proliferation of root tips, because air pruning in spring rings could lead to an increase in root-produced hormones. In short, the total plant biomass was not significantly different among the treatments. The highest percentage of deformed roots was observed when plants were grown in conventional containers; whereas, there were no differences in the percentage of deformed roots between plants grown in root trainers and spring rings. Our study show that air pruning technology and mechanical impediments on the inside walls of the container can be a useful tool to limit root deformation in container grown eucalyptus.

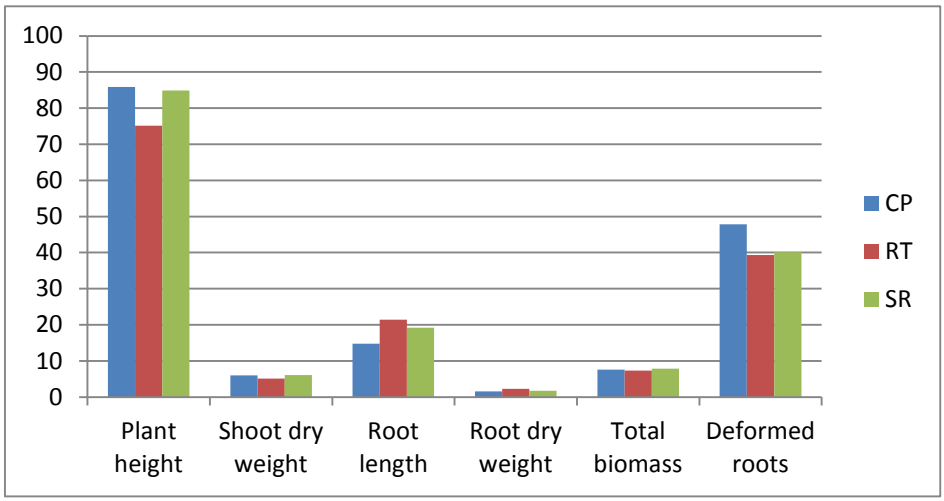


Fig 1.Mean of different Shoot and Growth parameters in relation to various containers

3.2. Container Design-Landscape Performance

Container design had small but significant effects on post-transplanting and field establishment. Field establishment, as measured by the rate of plant height and dry root biomass gain over the season after transplanting did not significantly vary between the treatments (Table 2). However, the root length significantly varied among the treatments. Due to the coiling and encircling of roots, the conventional planters had the least value of root length. Root restriction of seedlings grown in conventional containers resulted in long-term effects on plant performance after landscape planting. Root dry weights were greater in plants grown in modern containers. These responses were due to root circling, resulting in a less active root system from which new roots emerged slowly than from the modern containers (Sulecki,1988). It is well-recognized that tree survival and growth are strongly influenced by the root system. A positive pattern of root distribution was found in plants grown in spring ring planters. This would improve the ability to tolerate the harsh environment of Kuwait desert. Plants which were grown in the spring ring planters had root systems that were distributed evenly through the soil and in all directions. The effects of container design on plant growth did not persist to maturity (Cox, 1984), but there was a persistence of a slight difference in landscape performance.

Parameter	Spring Rings	Root Trainer	Conventional Pots	
Plant height(cm)	55.8	78.0	72.0	NS
Root biomass(g)	7.54	8.32	10.18	NS
Root length(g)	57.19b	63.3a	42.70c	*
Deformed roots (%)	28.9b	29.4b	43.1a	*

Table 2. Effect of Alternate Containers on Post-Transplanting in Arid Climate

The means within same row followed by different letters are significantly differed from each other using LSD, NS indicates non-significant at (P = 0.05).

From the observations and the data on post-transplanting, it was clear that plant growth was not affected by the container type. The plant root system was well-distributed in all directions when they were growing in the field, and no deformed roots were detected in plants that were initiated in spring ring planters. No doubt that even distribution of roots on the surface is important, and having long tap root system may be equally important. In summary, performance of eucalyptus appeared to be more sensitive to root restriction. For all practical purposes, container shape had no effect on landscape performance of Eucalyptus.

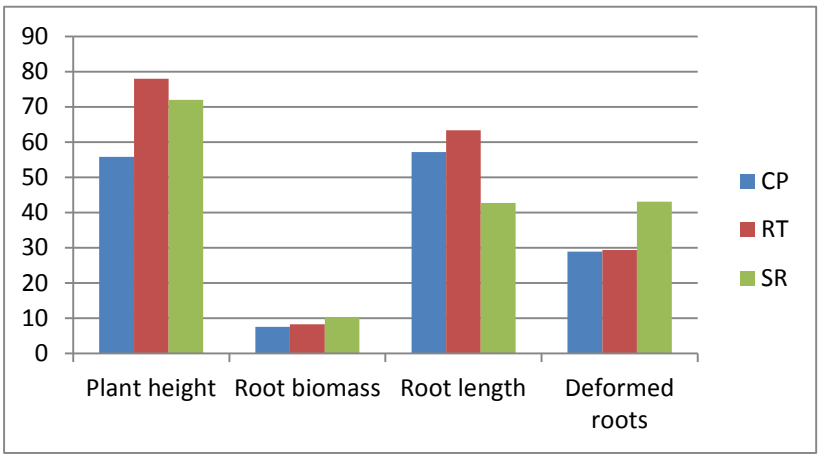


Fig 2.Mean of different Shoot and Growth parameters on Post- transplanting into the field

4. CONCLUSIONS

This study reveals that the different container shapes have a clear cut influence on the root system conformation in Eucalyptus regarding the impact of three different container shapes on shoot and root growth. Plants grown in conventional containers showed the highest percentage of deformed roots compared with plants grown in spring rings and root trainers. The containers with air-pruning or mechanical impediments have the lowest number of deformed roots and hence a good root architecture. Planter type could affect the aerial parts. On the other hand, the container type and shape had a direct impact on root architecture but not necessarily on root production. Air prune spring ring planter reduced the harmful root biomass and encircling of roots. The plant root system was well-distributed when grown in the field, and no deformed roots were detected in trees that were transplanted from spring ring containers. The effect of the spring rings on plants grown in the

landscape was obvious visually during research period in the short-term, but was not apparent from growth quantification. The field experiment revealed that the container shape had no effect on landscape performance of Eucalyptus.

REFERENCES

Arnold, MA 1996. Mechanical correction and mechanical avoidance of circling of roots differentially affect post-transplant root regeneration and field establishment on container-grown shumark oak. Journal of American Society of Horticulture Science 121: 258–263.

Arnold, MA. & McDonald, GV 2006. Shrub rose response to production in smart pots and conventional containers using two contrasting substrates. Subtropical Plant Science Journal of the Rio Grande Valley Horticultural Society 58:1–4.

ATREE, 2004. **A**shoka Trust for Research in Ecology and Environment Website, http://www.atree.org/Restoration article html, accessed April 2014.

Bhat, NR 1997. Screening of selected plants for landscape beautification and greenery development in Kuwait. Report No. KISR 5143, Kuwait Institute for Scientific Research, Kuwait.

Cox, E F 1984. The effect of shape of compost blocks on the propagation, transplant establishment and yield of four vegetable species. Journal of Horticultural Science 59:205–212.

Gilman, EF 2001. Effect of nursery production method, irrigation, and inoculation with mycorrhizae-forming fungi on establishment of Quercus virginiana. Journal of Arboriculture 29:231–236.

Gilman, EF, Grabosky, J & Stodola, A 2003. Irrigation and container type impact on Red maple (*Acer rubrum* L.) five years after landscape planting. Journal of Arboriculture 29(4): 131–135.

Gilman, EF, Paz, M & Harchick, C. 2010. Root ball shaving improves root system on seven tree species in containers. *Journal of Environmental Horticulture* 28:13–18.

Harris, RW 1992. Arboriculture Integrated Management of Landscape Trees, Shrubs and Vines. New Jersey: Prentice Hall.

Krizek, DT & Dubik, SP 1987. Influence of water stress and restricted root volume on the growth and development of urban trees. Journal of Arboriculture 13(2): 47–55.

Marler, TE & Willis, D 1996. Chemical or air-root pruning containers improve carambola, longam, and mango seedling root morphology and initial root growth after planting. Journal of Environmental Horticulture 14:47–49.

Marshall, MD &Gilman, EF 1998. Effects of nursery container type on root growth and landscape establishment of Acer rubrum L. Journal of Environmental Horticulture 15:55–59.

Moore, D 2001 Nursery practices and the effectiveness of different containers on root development. Treenet Proceedings of the 2nd National Street Tree Symposium: 6–7 September. ISBN 0-9775084-1-2.

Mullan, GD & White, PJ 2002. Seedling quality making informed choices. Department of Conservation and Land Management, Wheat belt Region, Western Australia.

Nesmith, DS & Duval JR 1998. The effect of container size. Horticulture Technology 8 (4):495 – 498.

Ngulube, MR 1989. Polythene tube sizes of rising Eucalyptus seedlings for dry land afforestration programmes in Malawi. Journal of Tropical Forestry 5 (1):30–35.

Ortega, U, Rodriguez, N, Gonzalez-Murua, C, Majada, J, Azpitarte, J, Txarterina, K & Dunabeitia, M 2001. Montes para la sociedad del Nuevo Milenio. III Congreso Forestal Espanol, Estudio de la calidad de planta de Pinus radiata en envase Junta de Andalucia. SE-2499-2001. Consejeria de Medio Ambiente III:354–359. (Spanish).

Ortega, U, Majada, J, Mena-Petite, A, Sanchez-Zabala, J, Rodriguez-Iturrizar, N, Txarterina, KAzpitarte, J & Dunabeitia, M 2006. Field performance of *Pinus radiata* D. Don produced in nursery with different types of containers. New Fortune 31:97–112.

Paz, H 2003. Root/shoot allocation and root architecture in seedlings: Variations among forest sites, microhabitats and successional groups. Biotropica 35:318–332.

Sulecki, JC 1988. It's hip to use square. Greenhouse Grower 6(2):66-68.

Taha, FK, Houkal, D, Hegab, A, Agarwal, V. El-Nasri E &. Khan M 1988. Plant testing program for the Kuwait waterfront project. Report No. KISR28995, Kuwait Institute for Scientific Research, Kuwait.

Tsakaldimi, M, Zagas, T, Tsitsoni, T & Ganatsas, P 2005. Root morphology, stem growth and field performance of seedlings of two Mediterranean evergreen oak species raised in different container types. Plant and Soil 278:85–93.

Tsakaldimi, MN & Ganatsas, PP 2006. Effect of chemical pruning on stem growth, root morphology and field performance of the Mediterranean pine *Pinus halepensis* Mill. Scientia Horticulturae 109:183–189.