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Influence of Container Design on Root Circling, Top Growth, and Post-Transplant Root Growth of Selected Landscape Species[1]

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Abstract

'Delaware Valley White' azalea, 'Green Luster' holly, 'Plumosa Compacta Youngstown' juniper, and 'Shasta' viburnum were grown for 1 to 2 years in four container designs: a conventional straight-walled round container, a square container with corner holes, a round container with stepped-pyramid profiles, and a poly bag. Poly bag, square, and stepped-pyramid containers significantly reduced root circling on all species compared to the traditional straight-walled round container. There were no significant differences in root circling among the three designs. Top growth was harvested at the end of 1 and 2 years. Effect of container design on top dry weight was species dependent. Poly bag, square, and stepped-pyramid containers increased top growth by 11 to 23% compared to the straight-walled round container. However, no one design was consistently superior for 2 years compared to the straight-walled round container. In addition, three of four species did not respond to container design 1 out of 2 years. Plants were transplanted into the landscape after growing for 1 or 2 years in the containers. After 16 weeks in the landscape, 'Green Luster' holly initially grown in poly bag, square, and stepped-pyramid containers had greater new root dry weight and smaller shoot (top):root ratios compared to the straight-walled round container. Top and new root dry weight of 'Shasta' viburnum were significantly affected by container design. However, the shoot:root ratios were not significantly different compared to the straight-walled round container. In the landscape, container design did not significantly affect top dry weight, new root dry weight or shoot:root ratio of 'Plumosa Compacta Youngstown' juniper.

Index words: nursery crops, plant establishment, container-grown, root spiraling

Species used in this study: 'Delaware Valley White' azalea (*Rhododendron* L. sp. 'Delaware Valley White'); 'Shasta' viburnum (*Viburnum plicatum* Thunb. var. *tomentosum* 'Shasta'); 'Green Luster' holly (*Ilex crenata* Thunb. 'Green Luster'); 'Plumosa Compacta Youngstown' juniper (*Juniperus horizontalis* Moench 'Plumosa Compacta Youngstown').

Significance to the Nursery Industry:

Poly bag, square, and stepped-pyramid container designs successfully minimized root circling compared to the straight-walled round container for all species evaluated. However, they did not consistently improve top growth over 2 years compared to the straight-walled round container. The effectiveness of new container designs in enhancing new root generation is species dependent. When planted in the landscape following growth in particular container designs, 'Green Luster' holly was the only species which responded positively to changes in root system morphology induced by initial container growth. Individual species should be tested before growers switch from the traditional straight-walled round container to other designs. The container should provide tangible improvements in growth before recommendations to switch container designs are made.

Introduction

Container production of landscape plants represents over one-half of all landscape plants sold in the United States (2). Unfortunately, container-grown plants often perform poorly after transplanting into the landscape (5, 8). This has been attributed to the smooth-walled, round container in

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which most plants are initially grown. With this container design plant roots grow around the container, producing circling (spiraling) roots. Circling roots continue to grow in a circular fashion after transplanting, while only slowly expanding radially into the soil (8). This increases water stress, reduces nutrient absorption, and causes inadequate anchorage (17). The longer the plant is held in a container, the more pronounced encircling roots become, amplifying lack of root growth into the soil following planting in the landscape.

To improve container-grown plant survival and growth in the landscape, cultural practices such as amended backfills have been evaluated. However, several studies have shown no consistent improvement in plant establishment or growth from the use of soil amendments (4, 9, 10). Mechanical disruption of the root ball is currently recommended before planting to encourage rapid root development into the surrounding soil (6, 7, 8). However, supporting data on the effectiveness of this treatment are limited and contradictory (3, 15, 20).

Research has demonstrated that modifications of the container side wall will minimize or prevent circling roots (1, 18), but there are conflicting data as to whether these designs affect shoot growth (11, 18). In addition, there have been few reports on the effectiveness of these container designs in promoting root growth from the root ball into the surrounding soil after transplanting (18). Therefore, the objective of this research was to determine the effect of four container designs on top growth during container production and subsequent top and root growth after transplanting into the landscape.

Materials and Methods

The study involved growing plants in four container designs for either 1 or 2 years (container production) and transplanting these container-grown plants into a simulated landscape for subsequent evaluation of top and root growth (landscape growth).

Container production. The study, a randomized complete block design with eight replications of four plants each, was conducted on a gravel pad located at the Mountain Horticultural Crops Research Station [35°26′N, 82°34′W, elev. 631 m (2051 ft)], Fletcher, NC. Rooted cuttings of 'Delaware Valley White' azalea, 'Green Luster' holly, 'Plumosa Compacta Youngstown' juniper, and 'Shasta' viburnum were potted into four container designs on May 5, 1987. The container designs were A) a conventional straight-walled round container (Poly-tainer, Nursery Supplies, Inc., Fairless Hills, PA 19030), B) a square container with corner holes (ARP-tainer, Nursery Supplies, Inc., Fairless Hills, PA 19030), C) a round container with stepped-pyramid profiles (Rootpruning container, Imperial Plastics, Evansville, IN 47706), and D) 0.1 mm (4 mil) thick poly bag (Menne Nursery Corp., North Tonawanda, NY 14120). All containers were 3.8 liters (4 qt), except for the square container which was 2.8 liters (3 qt). The first three containers were rigid plastic, the fourth a flexible thin plastic bag gusseted at the bottom like a paper bag.

Growth medium was milled pine bark (<13 mm) (0.5 in) amended per m^3 (yd^3) with 3.6 kg (6 lbs) dolomitic limestone and 0.9 kg (1.5 lbs) Micromax. Fifteen g (0.5 oz) of Osmocote 18N-2.6P-9.9K (18-6-12) (Sierra Chemical Co.) were surface applied on May 12, 1987. Soluble salts were monitored weekly (19). When the soluble salts level dropped below 0.50 mMhos on July 21, 1987, Osmocote was reapplied at the above rate. Plants received 1.3 cm (0.5 in) of water daily via overhead irrigation.

One plant from each species, container design, and replication (total of eight plants/container design/species) was randomly chosen on November 11, 1987. Top growth (aerial tissue) was cut at the medium surface and dried at 70°C (158°F) for 6 days and weighed. Because the roots could not be physically separated from the medium with any reasonable accuracy, dry weight was not obtained for roots. Before harvest, growth indices [height + (width + width)/2/2] were recorded, roots were visually rated for side and bottom circling on a scale of 1 to 5 (1 = no circling, 3 = moderate circling, 5 = extensive circling), and root development was rated by visually estimating the percent of root ball covered. The remaining plants were moved to an overwintering structure (white co-poly quonset tent) on November 28, 1987. Plants were irrigated as needed during overwintering. Plants were moved back to the gravel pad on April 11, 1988. Container cultural practices during 1988 were identical to those in 1987 with the following exceptions: 13 g (0.4 oz) dolomitic limestone, 3 g (0.1 oz) Micromax, and 15 g (0.5 oz) Osmocote 18-6-12 were surfaced applied to each container on May 6, 1988. Osmocote was reapplied on July 18, 1988. One plant from each species, container design, and replication (total of eight plants/container design/species) was randomly chosen on October 14, 1988. Harvesting procedures, growth measurements, and ratings were identical to those outlined previously. The remaining plants were moved to an overwintering structure (white co-poly quonset tent) on December 2, 1988.

Landscape growth. The study, a randomized complete block design with eight replications, was conducted at the Mountain Horticultural Crops Research Station, Fletcher, NC. In October 1987, the cecil clay soil (clayey Kaolinitic Thermic Typic Hapuldult) was amended to meet the pH and fertility levels recommended by the North Carolina Department of Agriculture (14). Raised beds, 1.2 m wide (4 ft), were constructed 3.5 m (8 ft) apart. On April 12, 1988, one plant from each species, container design, and replication (total of eight plants/container design/species) was randomly chosen and hand planted 1.5 m (5 ft) apart within each bed. Plants had been in the containers for 1 year. Plants were watered at planting and they received only ambient rainfall for the duration of the study (Table 1). After planting, the entire bed was covered with 7.5 cm (3 in) of aged hardwood bark. Weeds were controlled by hand. Ammonium nitrate (33% N) was surface applied at 168 kg/ha (150 lbs/A) on April 22, 1988. Growth indices [height + (width +

Table 1. Rainfall received during 1988 and 1989.

Month	1988 (cm)	1989 (cm)
April	9.9	8.8
May	4.1	14.2
June	2.1	29.9
July	7.8	18.4
August	7.3	15.5

width)/2/2] were recorded at planting and every 30 days thereafter. After 16 weeks, tops (aerial tissue) were removed at the soil surface and roots were manually excavated, shaved at the original root ball surface, and washed. Both tops and roots were dried at 70°C (158°F) for 6 days then weighed to obtain top and new root dry weight. Shoot (top) dry weight to new root dry weight ratio (S:R) was calculated using the following equation: top dry weight/new root dry weight.

On April 20, 1989, the remaining plants (total of eight plants/container design/species) were removed from the overwintering structure and planted into the simulated landscape previously described. Plants had been in the container for 2 years. Identical cultural practices were followed with ammonium nitrate applied April 29, 1989. After 16 weeks, plants were harvested and data recorded as previously described.

Statistical analysis. All data were analyzed by analysis of variance, with means separated by Fisher's LSD at the 0.05 level.

Results and Discussion

Container production. Poly bag, square, and stepped-pyramid containers significantly reduced root circling on all species compared to the straight-walled round container after 1 or 2 years (data not presented). This is similar to the results reported by Appleton (1). There were no significant differences in root circling among the poly bag, square, and stepped-pyramid designs. The percent surface of the root ball covered with roots was not affected by container design after 1 or 2 years. After 1 year, 'Delaware Valley White'' azalea, 'Green Luster' holly, 'Plumosa Compacta Youngstown' juniper, and 'Shasta' viburnum averaged 66, 71, 78, and 81% of the root ball covered with roots, respectively. After 2 years, percentages averaged 88, 88, 90, and 94%, respectively.

After 1 or 2 years in containers, growth indices and top dry weights produced similar results for all species. Thus, only top weights are reported. Effect of container design on top dry weight was species dependent (Table 2). 'Delaware Valley White' azalea grown in the square container had the largest top dry weight after 1 or 2 years, although it was not always significantly greater than the other container designs. Container volume has been shown to have an impact on plant growth (13). Even though the volume of the square container was only 75% of that of the other three container designs, it did not hinder azalea growth. However, the differences in volume should be noted when making growth comparisons.

Top dry weight of 'Green Luster' holly and 'Plumosa Compacta Youngstown' juniper were not affected by container design after 1 year (Table 2). After 2 years, top dry weight of 'Green Luster' holly in the poly bag, square, and stepped-pyramid containers was 13 to 17% greater than those in the straight-walled round container. At the end of 2 years, top dry weight of 'Plumosa Compacta Youngstown' juniper in the poly bag was the only design significantly larger (23%) than the plants in the straight-walled round container.

After 1 year, top dry weight of 'Shasta' viburnum in the stepped-pyramid container was 11% greater than those in the straight-walled round container. However, it was not significantly greater than the poly bag and square containers (Table 2). Container design did not affect top dry weight of viburnum after 2 years.

Table 2. Top dry weight of 'Delaware Valley White' azalea, 'Green Luster' holly, 'Plumosa Compacta Youngstown' juniper, and 'Shasta' viburnum after 1 or 2 years growth in four container designs.

Container design	Azalea		Holly	
	1 year	2 years	1 year	2 years
	Dry weight (g)			
Poly bag	17.1 b[z]	49.3 b	39.1 a	100.7 a
Square	19.6 a	65.6 a	38.1 a	100.1 a
Stepped-pyramid	18.7 ab	61.0 a	32.8 a	103.9 a
Straight-walled round	16.9 b	51.4 ab	33.7 a	88.8 b
	Juniper		**Viburnum**	
	1 year	2 years	1 year	2 years
	Dry weight (g)			
Poly bag	77.4 a	218.4 a	30.2 ab	100.7 a
Square	75.7 a	165.6 b	28.5 ab	93.1 a
Stepped-pyramid	68.0 a	193.3 ab	31.1 a	98.7 a
Straight-walled round	70.3 a	177.0 b	28.1 b	102.2 a

[z]Mean separation within columns for a species by LSD, 0.05 level.

Depending upon species and container design, top dry weight was increased by 11 to 23% compared to the straight-walled round container. This is in agreement with Rypma (12) and Whitcomb (16) who reported that poly bags improved growth 5 to 15%, compared to the straight-walled round container. In contrast, Newman and Follet (11) reported that top growth of laurel oak (*Quercus laurifolia* Michx.) was not significantly improved by the stepped-pyramid container compared to the straight-walled round container. Even though there were improvements in top growth by the selected containers, no design was consistently superior to the straight-walled round container. In addition, three of the four species did not respond to container design during 1 of 2 years. Thus, the major benefit of these new designs may be preventing or minimizing root circling.

Landscape growth. Due to drought in 1988 (Table 1) and a late spring frost in 1989, azaleas did not survive in the landscape. Therefore, azalea data are not presented. Survival was 100% for all other species. After 16 weeks in the landscape, growth indices and top dry weights produced similar results for all species. Thus, only top dry weights are reported.

After 16 weeks in the landscape, 'Green Luster' holly grown in the poly bags produced the largest top and new root dry weight regardless of number of years in the container (Table 3). However, these data were not always significantly different from the other designs. Poly bag, square, and stepped-pyramid containers had greater new root dry weight (excluding stepped-pyramid in year 1) and smaller S:R ratios compared to the straight-walled round container in both years. Since the moisture status of the growth medium in a container becomes unfavorable soon after transplanting into the landscape (5), increased root growth into the surrounding soil should improve plant survival and growth. These data suggest that container design can enhance new

Table 3. Top dry weight, new root dry weight, and shoot (top) to new root ratio (S:R) of 'Green Luster' holly and 'Shasta' viburnum after initial growth of 1 or 2 years in four container designs followed by 16 weeks in the landscape.

	'Green Luster' holly					
	1 year			2 years		
Container design	Dry weight (g) Top	Root	S:R[z] (g/g)	Dry weight (g) Top	Root	S:R (g/g)
Poly bag	51.8 a[y]	4.8 a	10.8 b	193.7 a	17.2 a	11.6 b
Square	48.6 ab	4.0 a	12.2 b	178.6 ab	13.4 b	14.2 b
Stepped-pyramid	32.5 b	2.2 b	14.8 b	168.2 b	14.7 ab	14.5 b
Straight-walled	37.4 b	1.6 b	23.4 a	159.1 b	7.9 c	22.5 a

	'Shasta' viburnum					
	1 year			2 years		
Container design	Dry weight (g) Top	Root	S:R[z] (g/g)	Dry weight (g) Top	Root	S:R (g/g)
Poly bag	132.1 b	22.7 b	6.0 a	260.4 a	31.4 b	8.3 a
Square	185.2 a	33.8 a	5.5 a	246.0 a	33.5 ab	7.5 a
Stepped-pyramid	182.1 a	31.8 a	5.8 a	272.3 a	42.6 a	6.5 a
Straight-walled	141.7 b	24.2 b	6.3 a	250.9 a	35.4 ab	7.3 a

[z]S:R = shoot (top) dry weight/new root dry weight.
[y]Mean separation within columns for a species by LSD, 0.05 level.

root generation of 'Green Luster' holly from the container root ball after transplanting. Similarly, Whitcomb and Williams (18) reported that the stepped-pyramid container promoted new root generation of gardenia (*Gardenia jasminoides* Ellis) and 'Mojave' pyracantha (*Pyracantha* M. J. Roem. × 'Mojave') after transplanting compared to a straight-walled round container.

After 16 weeks in the landscape, 'Shasta' viburnum grown for 1 year in square and stepped-pyramid containers had the largest top and new root dry weight (Table 3). There was no difference, however, in S:R ratios among container designs. After 2 years in containers and 16 weeks in the landscape, container design did not affect top dry weight or S:R ratio of 'Shasta' virburnum. New root dry weight of 'Shasta' virburnum was affected but poly bag, square, and stepped-pyramid containers were not significantly different from the straight-walled round container. Lack of improved new root generation after 2 years may indicate that the container designs are effective up to a certain point, after which the designs are no longer effective in promoting new root growth.

In the landscape, container design did not significantly affect top dry weight, new root dry weight or S:R ratio of 'Plumosa Compacta Youngstown' juniper. Top dry weight, new root dry weight and S:R ratio for all container designs averaged 248.0, 19.8, and 12.6 after 1 year in containers and 488.7, 33.2, and 14.7 after 2 years in containers, respectively.

Even though poly bag, square, and stepped-pyramid container designs minimized root circling, only 'Green Luster' holly demonstrated increased new root generation in the landscape over both years. Assuming increased root growth translates into reduced water stress and increased nutrient absorption, this could improve survival and growth of container-grown plants. However, for new container designs to be of value, those species which respond positively in the landscape to container design need to be identified.

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