Initial Plant Size and Landscape Exposure Affect Establishment of Transplanted *Kalmia latifolia* 'Olympic Wedding'[1]

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Abstract

Effects of plant size and landscape exposure on survival and subsequent growth of transplanted, container-grown mountain laurel (*Kalmia latifolia* L. 'Olympic Wedding') were studied at two locations. Plants of 'Olympic Wedding' mountain laurel grown in 1, 7.5, or 19 liter (1 qt, 2 gal, or 5 gal) containers for 1, 2, or 3 years, respectively, were transplanted in Raleigh, NC, and Blacksburg, VA, in tilled beds amended with pine bark along four exposures (north, south, east, and west). In Raleigh, survival increased with increasing container size with plants grown initially in 19 liter containers having the highest rate of survival whereas, survival was greatest on the east and north exposures and lowest on the west exposure. There was no difference in survival between container sizes or exposures for plants grown in Blacksburg. After three growing seasons in the landscape, visual ratings in Raleigh were higher for plants grown initially in 7.5 liter (2 gal) containers than for plants grown in 1 (1 qt) or 19 liter (15 gal) containers. Visual ratings were higher on north and east exposures than on south and west exposures regardless of container size. In Blacksburg, percent leaf scorch was lower for 1 and 7.5 liter (1 qt and 2 gal) plants, than for 19 liter (5 gal), and was highest on west exposures. Growth index (GI) increased 118% from 1999 to 2001 in Raleigh and 225% from 1999 to 2002 in Blacksburg for 1 liter (1 qt) plants and 51% in Raleigh and 78% in Blacksburg for 7.5 liter (2 gal) plants over the course of the experiment. There was an initial increase in GI for 19 liter (5 gal) plants in both locations, but in subsequent years GI decreased due to stem dieback. In Raleigh, GI of 7.5 liter (2 gal) and 19.5 liter (50 gal) plants grown on the east exposure was greater than plants grown on the south exposure with no difference due to exposure at Blacksburg. Results suggest that in climates similar to Raleigh, initial container size and exposure affect survival of transplanted mountain laurel, but in cooler climates like Blacksburg, initial container size and exposure may not be critical factors except in windy exposures.

Index words: mountain laurel, woody ornamental, container-grown, temperature, Ericaceae.

Significance to the Nursery Industry

Improving survival of transplanted, container-grown mountain laurel (*Kalmia latifolia)* may encourage increased commercial production and use of this native plant species. Research herein examined the effects of initial plant size and landscape exposure on establishment of transplanted mountain laurel in Raleigh, NC, and Blacksburg, VA. Results indicated that in warmer climates similar to Raleigh, planting mountain laurel in shaded locations may improve survival of this species following transplanting, while exposure does not appear to affect survival in cooler climates similar to Blacksburg. In addition, mountain laurel transplanted from 7.5 liter (2 gal) containers outperformed mountain laurel transplanted from 1 liter (1 qt) or 19 liter (5 gal) containers after 3 or 4 years in the landscape in Raleigh and Blacksburg, respectively. It is suggested that growers market mountain laurel earlier in its production cycle to achieve a higher container volume:top ratio that may improve landscape establishment of this ornamental species.

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Introduction

There are many factors that influence the ability of woody ornamental plants to survive transplanting from containers into the landscape, including initial plant size (8). Growth of smaller trees may eventually equal or surpass growth of larger trees transplanted at the same time (20). Plant biomass of crape myrtle (*Lagerstroemia indica* L. x *Lagerstroemia fauriei* Koehne 'Tonto') was highest 16 weeks after transplanting for plants that had the smallest plant dry weight, canopy size, and leaf area (compared to other plants in the same experiment) at time of transplanting (6). Transplant size affects root:top ratio (8), and in the case of transplanted trees, smaller plants may have a higher root:top ratio (20). A larger root:top ratio is particularly important for providing adequate water via the roots to replenish water lost via transpiration. Maintaining such a water balance within the plant is critical for transplant survival (12). Since the root:top ratio can change with time, age, and production practices in the nursery, it is likely that root:top ratios may vary widely, depending on multiple factors (4, 11).

Exposure in the landscape also affects transplant survival and may be particularly important for plants traditionally planted in full to partial shade. 'Pink Ruffles' azalea (*Rhododendron* L. x 'Pink Ruffles') had lower top and root dry weight when grown in full sun than when grown in shade (2), and Japanese aucuba (*Aucuba japonica* Thunb.) exhibited chlorosis, necrosis, and dieback when transplanted from shade into full sun (1). In addition, variation in air and soil temperatures among exposures may account for differences in survival and growth. Cultivars of blue holly (*Ilex* x *meserveae* S.Y. Hu) performed best when planted on northern exposures (compared to other exposures) where summer foliage temperatures were coolest (17). Exposure can also influence plant water relations. 'China Girl' holly (*Ilex rugosa* Friedr. Schmidt. x *I. cornuta* Lindl. & Paxt.) had lowest leaf water potential when grown on southern exposures (15). Additionally, root growth and distribution are influenced by exposure. Roots of several transplanted tree species were concentrated on the north and east sides of the root ball (21).

Mountain laurel is an attractive, broadleaved evergreen shrub that produces an impressive floral display during late spring to early summer. Although most commonly found growing in shady understory locations, this species also grows in full sun in cooler climates and in the mountains of the southeastern United States (personal observations). Despite its extensive native range in the eastern United States (Maine to Florida), it frequently does not survive transplanting into the landscape even in areas to which it is indigenous (7, 10). Therefore, the objective of this research was to determine the effect of transplant size and landscape exposure on establishment of transplanted mountain laurel.

Materials and Methods

Research was conducted at the Horticulture Field Laboratory, North Carolina State University, Raleigh [elevation 134 m (434 ft), lat. 35°77'N, long. 78°64'W, USDA cold hardiness zone 7B, AHS heat zone 7] and at the Urban Horticulture Center, Virginia Tech, Blacksburg [elevation 615 m (2000 ft), lat. 37°11'N, long. 80°25'W, USDA cold hardiness zone 7A, ARS heat zone 4]. The locations were chosen to represent a warmer (Raleigh) and a cooler (Blacksburg) climate. Average monthly temperatures for Blacksburg are –1, 0, 5, 10, 15, 19, 21, 21, 17, 11, 6, and 1C (30, 32, 42, 51, 59, 67, 71, 71, 63, 52, 43, and 34F) for January through December, respectively, whereas, average temperatures for Raleigh are 3, 5, 10, 15, 19, 23, 25, 25, 21, 15, 10, and 5C (39, 42, 50, 59, 67, 74, 78, 78, 71, 60, 51, and 43F) for January through December, respectively. Exposures in four directions (north, south, east, and west) were provided by square structures constructed from four panels of 1.8 m (6 ft) tall × 2.4 m (8 ft) wide spruce fencing material. Fencing panels consisted of twenty-three 10 cm (4 in) wide slats per panel with 0.6 cm (0.25 in) spacing between slats. Six structures were constructed at each location, each representing one block (replication). Coordination between the two locations was maintained for the critical areas: soil preparation, construction of structures, rate of fertilization, plant material, time of evaluations, and growth data, however, not all data collected were identical. Any data that were not collected in a similar manner between sites is explained in the following text.

Tilled beds [1.2 m (4 ft) wide] were prepared adjacent to each side of a structure. Prior to planting, the Cecil clay soil (clayey, kaolinitic, thermic Typic Hapludult) in Raleigh and the Groseclose silt loam soil (clayey, mixed, mesic Typic Hapludults) in Blacksburg, were amended by incorporating 5 cm (2 in) composted milled pine bark [< 1.25 cm (0.5 in)], and pH, phosphorus, and potassium were adjusted to recommended levels for mountain laurel in the landscape (5, 19). After planting and at the beginning of each growing season, beds received 0.03 kg/m^2 (0.6 lb/yd^2) 18N–6P_2O_5–12K_2O Osomcote™ controlled release fertilizer (8–9 month formulation, Scotts-Sierra, Marysville, OH) and 10 cm (4 in) composted wood chip mulch. Plants used in this study were micropropagated 'Olympic Wedding' mountain laurel liners (Briggs Nursery, Olympia, WA) grown in 1, 7.5, or 19 liter (1 qt, 2 gal, or 5 gal) containers at Historyland Nurseries, Inc., Montross, VA, for 1, 2, or 3 growing seasons respectively. John Eichelser Olympia, WA, developed *Kalmia latifolia* 'Olympic Wedding' from controlled crosses between *K. latifolia* 'Ostbo Red' and *K. latifolia* 'Fresca'. At planting, plants averaged 8.5 cm ± 0.5 SE (3.4 in) and 8.2 cm ± 0.9 SE (3.2 in), 23.0 cm ± 1.4 SE (9.1 in) and 20.1 cm ± 2.2 SE (7.9 in), 62.5 cm ± 2.8 SE (24.6 in) and 46.7 cm ± 4.3 SE (18.4 in), for 1, 7.5, or 19 liter (1 qt, 2 gal, or 5 gal) containers for height and width, respectively. The roots of all plants in all container sizes had completely exploited the container volume. For simplicity, mention of plants throughout the manuscript will be referred to by the size of the container in which the plants were grown initially.

In May 1999, plants were planted in the tilled beds surrounding each structure. Two rows of plants running lengthwise along each side of a structure were planted with one plant of each size per row. Plants in the inside row were 0.2 m (8 in) from the structure and were evenly spaced 0.6 m (2 ft) from each other. The outside row was 0.5 m (20 in) from the inside row with similar spacing between plants. To minimize shading of plants in the inner row, plants in the outside row were offset from plants on the inside row by 0.15 m (6 in) towards the north or east on all sides. Plants were randomized by size within each row. In Blacksburg, only one row of plants was planted along each exposure with a single plant of each size per row.

All plants were irrigated [2.5 cm (1 in) water] twice weekly during the first 30 days of the study. In Raleigh, soil moisture at each exposure was measured three times weekly using Watermark Soil Moisture Sensors (–300 kPa capacity, Irrometer Co., Riverside, CA) installed in the soil [15 cm (6 in) depth] outside the root ball of one plant of each size per exposure (total of 12 sensors per block). Sensors were installed in this manner for two blocks (total of 24 sensors). Plants in Raleigh were irrigated during the first growing season with 2.5 cm (1 in) of water when the average soil moisture tension reached –30 kPa (–30 cbar). The moisture sensors were placed outside the rootballs as these sensors are not effective in organic substrates. Plants grown in Blacksburg during the first growing season were irrigated as needed based on visual evaluations. Plants received no irrigation during subsequent growing seasons.

Leaf temperature in the horizontal and vertical center of the canopy of one plant of each size per exposure was measured in Raleigh by attaching a copper-constantan thermocouple to the underside of a leaf. Thermocouples were attached to the leaf using water resistant contact cement (Weldwood, DAP Inc., Dayton, OH). Soil temperature at each exposure was measured by inserting a similar thermocouple into the soil at a depth of 10 cm (4 in). Leaf and soil temperatures were measured every 15 min for three blocks, and hourly average, maximum, and minimum temperatures were recorded (23X Micrologger, Campbell Scientific Inc., Logan, UT). As massive amounts of temperature data were generated, data for average hourly leaf and soil temperatures at each exposure are presented for August 29, 2000, as representative of the general trends and differences in temperatures among exposures throughout the year.

Plants were grown for three (1999–2001) or four (1999–2002) growing seasons in Raleigh and Blacksburg, respectively. With the exception of 2001 for plants grown in Blacksburg, plant death or survival was recorded for each plant after each growing season. Nondestructive growth in-

Table 1. **Visual rating scale used for evaluation of overall quality of the tops of 'Olympic Wedding' mountain laurel grown in Raleigh.**

Rating	Overall quality
1	≤ 25% top tissue living
2	26 to 50% of top tissue living
3	51 to 75% top tissue living
4	> 75% top tissue living
5	No death, vigorous growth

dex (GI) measurements {plant height + [(maximum plant width + perpendicular width) ÷ 2]} were recorded for all plants at experiment initiation (May 1999) and for all living plants after each growing season. After each growing season, living plants were rated visually for overall quality of the tops in Raleigh (Table 1). In Blacksburg, overall quality of living plants was evaluated by estimating the percent scorched and dead foliage on each plant. Experiments were terminated November 2001 in Raleigh and November 2002 in Blacksburg. At experiment termination in Raleigh, tops (aerial portions) of all plants were cut at the soil level and separated into stems and leaves and dried at 70C (160F) to constant weight and weighed. In Raleigh, initial leaf area was measured for two plants of each size (nonplanted), and prior to drying, final leaf areas of all plants were measured using a LI-COR 3000 leaf area meter (LI-COR, Inc., Lincoln, NE). Since it was not possible to separate the roots from the container media at planting, initial root:top ratio for each plant size was calculated as container (root) volume ÷ leaf area. Leaf area:top dry weight ratio was calculated as leaf area ÷ top dry weight. Rootballs of plants of each size on all exposures (two blocks) were excavated in Raleigh by hand digging, and root systems were observed visually for extent of root growth into soil (not quantified).

The experiments at each location were a split plot design with six blocks. Within each block, exposure formed the main plots, and initial plant size formed the subplots (split-plot). In cases where repeated measurements were taken over time, measurement date was treated as a sub-subplot (split-split plot) factor. Data collected for plant growth and environmental conditions were analyzed for significance of treatment main effects and interactions using general linear models procedures. Means were generated using LSMEANS and separated by PDIFF at $P = 0.05$ (18). The effect of planting row in Raleigh was not significant, so all data presented are averaged over row.

Table 2. **Effect of initial container size and exposure on final evaluations of survival, overall plant quality (Raleigh), and leaf scorch (Blacksburg) of 'Olympic Wedding' mountain laurel and significance of main effects and interactions.**

	Survival (%)		Overall visual top quality[z]	Leaf scorch (%)
	Raleigh	Blacksburg	Raleigh	Blacksburg
Container size				
1 liter	21c[y]	92	2.0b	18b
7.5 liter	65b	91	3.5a	11b
19 liter	100a	97	2.6b	28a
Exposure				
North	78a[x]	100	4.0a	16b
South	72b	94	1.8b	6b
East	83a	89	3.4a	9b
West	56c	100	1.8b	32a
Significance[w]				
Size	***	NS	**	**
Exposure	**	NS	**	**
Size × exposure	NS	NS	NS	NS

[z]See Table 1 for the visual rating scale.

[y]Lowercase letters within columns denote mean separation among plant size by PDIFF at $P \leq 0.05$.

[x]Lowercase letters within columns denote mean separation among exposures by PDIFF at $P \leq 0.05$.

[w]NS, **, *** Nonsignificant or significant at $P \leq 0.01$ or 0.001, respectively.

Results and Discussion

Effect of initial container size. In Raleigh, survival of 'Olympic Wedding' mountain laurel was lowest among 1 liter (1 qt) plants, while no death occurred among 19 liter (5 gal) plants (Table 2). Plant survival in Blacksburg was similar for all sizes. For both locations, the effect of container size on plant quality was similar throughout the course of the experiment (data not presented), so results are presented for the final evaluation. In Raleigh, overall top quality was higher for plants grown in 7.5 liter (2 gal) than plants grown in 1 or 19 liter (1 qt or 5 gal) containers (Table 2). In Blacksburg 1 and 7.5 liter (1 qt and 2 gal) plants had less leaf scorch than 19 liter (5 gal) plants (Table 2).

Growth index (GI) increased 118% from 1999 to 2001 in Raleigh and 225% from 1999 to 2002 in Blacksburg for 1 liter (1 qt) plants and 51% in Raleigh and 78% in Blacksburg for 7.5 liter (2 gal) plants over the course of the experiment (Table 3). There was an initial increase in GI for 19 liter (5 gal) plants in both locations, but in subsequent years GI decreased due to stem dieback (Table 3). In Raleigh, GI was highest on the north and east exposures for 7.5 liter (2 gal) plants, east exposure for 19 liter (5 gal) plants, and was similar at all exposures for 1 liter (1 qt) plants (Table 3). In Blacksburg, GI measurements were similar at all exposures.

Based on visual observations, plants in Raleigh transplanted from 7.5 liter (2 gal) containers appeared to have the most root growth at the end of the experiment. Final leaf area and top dry weight were dependent on initial container size, and thus were larger for 19 liter (5 gal) plants than for 1 and 7.5 liter (1 qt and 2 gal) plants (Table 4).

Effect of exposure. Percentage survival was highest on the east and north exposures and lowest on the west exposure in Raleigh (Table 2) with no difference due to exposure in Blacksburg (Table 2). Visual ratings were about two times higher for plants grown on the north and east exposure than for plants grown on south and west exposures in Raleigh (Table 2). In Blacksburg, plants grown on west exposure had more leaf scorch than those grown on other exposures which may be a reflection of more windy conditions on the western exposures. In Raleigh, leaf area and top dry weight were higher for plants grown on the east exposure compared to those grown on south and west exposures (Table 4).

Data for average hourly leaf and soil temperatures at each exposure in Raleigh are presented for August 29, 2000, as representative of the general trends and differences in temperatures among exposures throughout the year. In general,

Table 3. Effect of initial container size and season on growth index, plant size and exposure on growth index, and significance of main effects and interactions for growth index in Raleigh and Blacksburg.

	Growth index (GI)[z]					
	Initial container size					
	1 liter		7.5 liter		19 liter	
	Raleigh	Blacksburg	Raleigh	Blacksburg	Raleigh	Blacksburg
Season[y]						
At planting	16c[x]	24d	43d	58c	109b	143c
1999	28b	46c	51c	85b	123a	170a
2000	37a	68b	61b	103a	118ab	155b
2001	35a	—	65a	—	114b	—
2002	—	78a	—	103a	—	140c
Exposure						
North	30	56	62a[w]	87	113bc	153
South	25	51	51b	85	111c	150
East	28	51	61a	85	121a	153
West	34	55	46b	89	118ab	153
	Raleigh	Blacksburg				
Significance[v]						
Container size	***	***				
Exposure	**	NS				
Season	***	***				
Size × exposure	**	NS				
Size × season	***	***				
Exposure × season	NS	*				

[z]Growth index = {plant height + [(maximum plant width + perpendicular width) ÷ 2]}.

[y]GI measurements were taken at the conclusion of the growing season shown. At planting was taken at treatment initiation (May 1999).

[x]Lowercase letters within columns denote mean separation among seasons within plant size by PDIFF at $P < 0.05$.

[w]Lowercase letters within columns denote mean separation among exposures within plant size by PDIFF at $P < 0.05$.

[v]Interactions not shown were nonsignificant at $P \le 0.05$. NS,*, **, *** Nonsignificant or significant at $P \le 0.05$, 0.01, or 0.001, respectively.

Table 4. Effect and significance of initial container size and exposure on final leaf area, top dry weight, and leaf area:top dry weight of 'Olympic Wedding' mountain laurel grown in Raleigh.

	Leaf area (cm^2)	Top dry weight (g)	Leaf area:top dry weight[z]
Container size			
1 liter	467b[y]	32b	11.6a
7.5 liter	1052b	86b	11.2a
19 liter	2609a	332a	7.6b
Exposure			
North	1754ab[x]	180ab	11.14b
South	837b	127b	7.34c
East	2258a	183a	14.59a
West	657b	108b	7.46c
Significance[w]			
Size	***	***	**
Exposure	*	*	***
Size × exposure	NS	NS	NS

[z]Leaf area:top dry weight = leaf area ÷ top dry weight.

[y]Lowercase letters within columns denote mean separation among plant size by PDIFF at $P \le 0.05$.

[x]Lowercase letters within columns denote mean separation among exposures by PDIFF at $P \le 0.05$.

[w]NS, *, **, *** Nonsignificant or significant at $P \le 0.05$, 0.01, or 0.001, respectively.

leaf and soil temperatures were higher on south and west exposures than north and east exposures (Fig. 1).

Although leaf area and top dry weight of 19 liter (5 gal) plants were highest due to larger initial size at planting (Table 4), final GI measurements of these plants were similar to those at planting in both locations (Table 3). This is in stark contrast with the change in GI measurements of 1 and 7.5 liter (1 qt and 2 gal) plants, which increased over 100 and 50%, respectively, for the same time period. Similarly, Hanson et al. (9) reported that after three growing seasons canopies of 7.5 liter (2 gal) container-grown mountain laurel had a greater percentage increase than the canopies of 19 liter (5 gal) plants. In Raleigh, leaf area:top dry weight was lower for 19 liter (5 gal) plants than other plant sizes (Table 4), indicating the amount of foliage per initial container size was higher for 1 and 7.5 liter (1 qt and 2 gal) plants. Loss of leaves on 19 liter (5 gal) plants as a result of stem dieback was likely caused by plant water stress. In previous work, drought tolerance of 'Olympic Wedding' mountain laurel was much lower than that of 'Compacta' holly (24). Hanson et al. (9) also reported 19 liter (5 gal) container-grown mountain laurel were more stressed than 7.6 liter (2 gal) plants. Similarly, plants of 'Lodense' privet (*Ligustrum vulgare* L. 'Lodense') that received infrequent irrigation following transplanting were more sparsely foliated than those that received irrigation every 5 to 6 days (3). The higher leaf area:top dry

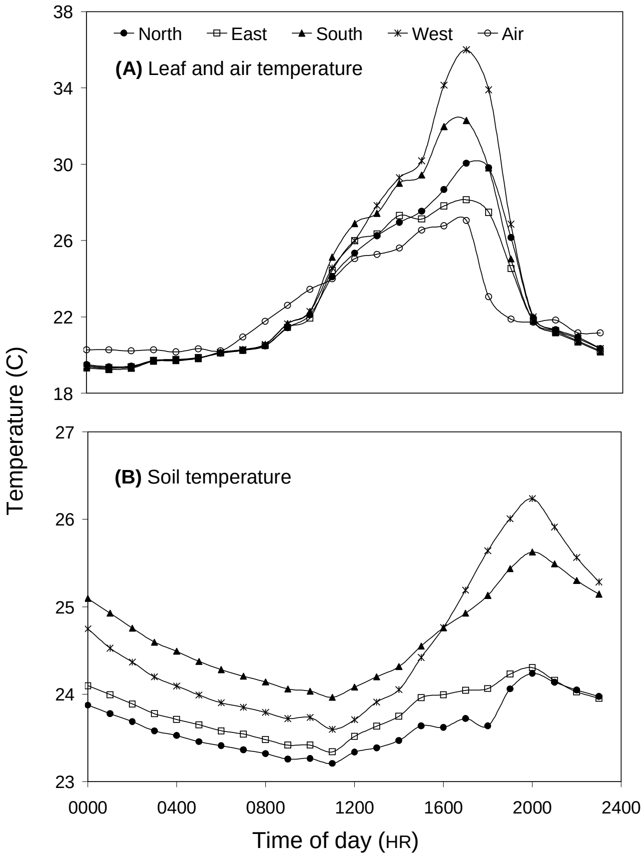

Fig. 1. Average hourly (A) leaf and (B) soil temperatures at each exposure in Raleigh, NC, for August 29, 2000, as representative of the general trends and differences in temperatures among exposures throughout the year. Legend in (A) applies to (B). Symbols in (A) and (B) represent means of nine and three observations, respectively.

weight of plants grown in 7.5 liter (2 gal) compared to plants grown in 19 liter (5 gal) containers (Table 4) may be a quantitative reflection of the high visual quality of the plants grown in 7.5 liter (2 gal) containers (Table 2).

At final harvest in Raleigh, all 19 liter (5 gal) plants were living, while 21% of the 1 liter and 65% of the 7.5 liter (1 qt and 2 gal) plants remained alive (Table 2). In Blacksburg, survival was > 91% for all plant sizes. Although surviving 1 liter plants had large increases in GI, their extremely high mortality rate in Raleigh suggests they are unsuitable for transplanting in full sun in warmer climates. Despite low mortality of 19 liter (5 gal) plants, their extremely low visual quality in Raleigh, high incidence of leaf scorch in Blacksburg, and minimum increase in GI at both locations over the duration of the investigation suggest that death of these plants may have commenced with time. The authors and other researchers have observed that mountain laurel and other members of the Ericaceae, such as Japanese andromeda (*Pieris japonica* D. Don), frequently die several growing seasons after transplanting (7).

Plants grown in 1, 7.5, and 19 liter (1 qt, 2 gal, and 5 gal) containers had initial root:top ratios of 0.002, 0.007, and 0.004, respectively. In the present experiment, plants grown in 7.5 liter (2 gal) containers performed best at both locations, and their superior visual quality and performance may be attributed to their higher initial root:top ratio. Root:top ratio influences the relationship between water uptake via the roots and water loss via transpiration (12). Since a large, attractive plant canopy is typically the goal of commercial production, frequent watering and high fertility common during nursery production may also result in more top growth than can be adequately supplied by the accompanying rootball following transplanting (8, 22). Such a situation could likely increase the need for intensive post-transplant care and irrigation. Thus, we stress that the effect of initial plant size in this experiment with regard to landscape establishment is attributed more to the root:top ratio at planting rather than the container size. Additionally, because initial root:top ratios were not intentionally manipulated for this experiment prior to transplanting, it appears that it is possible within the normal production cycle for nursery growers to produce plants of mountain laurel with a root:top ratio favorable for transplanting.

In the current study, plants in Raleigh with the best visual quality and most top growth within each size also appeared to have the most root growth. At experiment termination, size of root systems of 7.5 liter (2 gal) plants equaled or surpassed that of 19 liter (5 gal) plants (visual observations). Lack of extensive root growth in this study may have been due to soil texture. Although pine bark was incorporated into the soil prior to planting, heavy clay soils such as those in Raleigh may present a physical barrier to growth of roots of mountain laurel, which are very fine and fibrous (hair-like). Lack of root penetration into the surrounding soil due to dissimilarity in physical properties between container substrate and a mineral soil was reported for winged euonymus [*Euonymus alatus* (Thunb.) Siebold 'Compactus'] (14). In its native environment, root distribution of mountain laurel is typically concentrated in the upper organic litter layer (personal observations). In our experiment, most root growth appeared to occur in the mulch layer, suggesting the importance of mulch for root growth and development of mountain laurel.

In Raleigh, percentage survival and visual ratings were highest on north and east exposures (Table 2). Similar impact of exposure has been reported for transplanted rhododendron and azalea (*Rhododendron* L. sp.), in which transplant survival was highest and flowering was best on northern exposures (16). In that study, many plants along southern exposures died after one particularly hot summer, similar to results in the current study in that plant death occurred during summer rather than winter months. In contrast, exposure did not have a significant effect on survival in Blacksburg, suggesting that in cooler climates, exposure may not be critical for transplant survival.

More growth on north and east exposures in Raleigh was likely due to lower leaf and soil temperatures at these exposures. Similar to results in the current study, three cultivars of boxwood (*Buxus* L. sp.) had better visual quality and more growth when grown on north and east exposures than when grown on south exposures (13). In research conducted with transplanted blue hollies, although soil water supply was adequate at southern exposures, increased plant canopy temperatures associated with southern exposures negatively influenced plant growth (17). In previous work, lack of tolerance of mountain laurel to high root-zone temperature was documented, and the optimum experimental root-zone temperature [16C (61F)] was substantially lower than summertime soil temperatures recorded in the current experiment

(23). Although air and soil temperatures presented for August in Raleigh were among the highest temperatures of the year, temperature trends and differences between exposures for both leaf and soil were similar for other months. Additionally, soil temperatures observed in this study are representative of those that may actually be encountered in a landscape situation, since mulch was maintained throughout the experiment. Differences in temperature between exposures that occur during summer months are likely most important, since winters in Raleigh tend to be mild. As with survival, growth was not influenced by exposure in Blacksburg, again illustrating this aspect of transplanting may not be critical in cooler climates.

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