# Effects of Transplant Season and Container Size on Landscape Establishment of *Kalmia latifolia* L.[1]

**Anne-Marie Hanson, J. Roger Harris, and Robert Wright**[2]
*Virginia Polytechnic Institute and State University*
*Department of Horticulture, 301 Saunders Hall, Blacksburg, VA 24061*

## Abstract

Mountain laurel (*Kalmia latifolia* L.) is a common native shrub in the Eastern United States; however, this species can be difficult to establish in landscapes. Two experiments were conducted to test the effects of transplant season and container size on landscape establishment of *Kalmia latifolia* L. 'Olympic Wedding'. In experiment one, 7.6 liter (2 gal) and 19 liter (5 gal) container-grown plants were planted into a simulated landscape (Blacksburg, VA, USDA plant hardiness zone 6A) in early fall 2000 and in late spring 2001. Plants in 19 liter (5 gal) containers had the lowest leaf xylem potential (more stressed) near the end of the first post-transplant growing season, and leaf dry weight and area were higher for spring transplants than for fall transplants. For spring transplants, 7.6 liter (2 gal) plants had the highest visual ratings, but 19 liter (5 gal) plants had the highest visual ratings for fall transplants three growing seasons after transplanting. Plants grown in 7.6 liter (2 gal) containers had the highest % canopy volume increase after three post-transplant growing seasons. In the second experiment, 19 liter (5 gal) plants were transplanted into above-ground root observation chambers (rhizotrons) in early fall 2000 and late spring 2001. Roots of fall transplants grew further into the backfill than spring transplants at the end of one post-transplant growing season. Overall, our data suggest that smaller plants will be less stressed the first season after transplanting and will likely stand a better chance for successful establishment in a hot and dry environment. Fall is the preferred time to transplant since capacity for maximum root extension into the backfill will be greater than for spring transplants.

**Index words:** water stress, xylem potential, root growth, rhizotron.

## Significance to the Nursery Industry

Mountain laurel is a valuable container-grown crop, and the many flower colors available have broad appeal to garden center shoppers when plants are in full flower. Landscape establishment of mountain laurel, however, is difficult, and customers are often disappointed when plants die after transplanting to their home landscapes. Data from this study indicated that in climates similar to the Appalachian Mountain region of Western Virginia, transplanting in fall will improve transplant survival and subsequent growth. Retailers should consider marketing plants with color pictures of blooms to enhance fall rather than spring-only sales. Although landscape-sized 5 gal (19 liter) plants can be successfully transplanted, they may encounter more tissue water stress after transplanting than 2 gal (7.6 liter) plants. This stress will probably be exacerbated when summers are hot and dry.

## Introduction

Mountain laurel has been touted as 'the perfect shrub' for its beauty, extent of its range, and economic value to the nursery industry (12). Mountain laurel is a broad-leaved evergreen shrub, sometimes reaching the stature of a small tree in the Appalachian Mountains in the Eastern United States. Its native range is from Northern Florida to Maine, and mountain laurel can be found growing in various soil types and in a wide range of environmental conditions (12). However, container-grown mountain laurel in pinebark substrate, commonly propagated by tissue culture, is relatively difficult to establish into the landscape, often resulting in death (2).

Season of transplant influences transplant success through seasonal effects on biological status, such as bud dormancy and the associated hormonal signals (18, 19), root growth periodicity (4, 8), and weather, such as soil moisture (5, 14) and temperature (13, 15). Fall transplanting of trees and shrubs may be advantageous compared to spring transplanting in part because soils are generally moist and transpiration is reduced in fall and winter. In addition, more time is available for plants to acclimate to the new environments before the onset of the growing season (8). The additional time before spring budbreak for fall- vs. spring-transplants potentially results in root growth before the onset of limiting winter temperatures, although field-grown trees that are harvested and planted in the fall may not grow new roots until soil temperatures warm in the spring. Harris et al. (11) reported that root growth of early fall-transplanted Turkish hazelnut (*Corylus colurna* L.) trees did not begin new root growth until spring, although fall-transplanted trees began root growth before spring-transplanted trees. Another study addressing early root system regeneration of sugar maple (A*cer saccharum* Marsh.) and northern red oak (*Quercus rubra* L.) determined that although October-transplanted trees did not begin root growth until spring, root system regeneration began earlier and produced more roots in the first-season post-transplant than November- and March-transplanted trees (9). Container-grown plants may have more potential to grow roots in the fall than field-grown plants since container-grown root systems are not necessarily disturbed at planting. This potential may be heightened for plants such as mountain laurel, whose roots grow at relatively cool temperatures (24).

Smaller plants often establish faster than larger plants. Lauderdale et al. (16) transplanted balled and burlapped 3.8 cm (1.5 in) and 7.6 cm (3 in) trunk diameter red maples (*Acer rubrum* L.). Smaller plants had higher leaf conductance, water use efficiency, and shoot elongation, indicating less transplant stress than larger plants. They concluded that smaller plants are better candidates for transplanting in most circumstances since they recover from transplant shock more quickly than larger plants. Wright et al. (23) reported that 7.6 liter (2 gal) container-grown mountain laurel had a better visual rating and a larger increase in growth compared to plants in 19

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[2]Former Graduate Assistant, Associate Professor, and Professor, respectively.

liter (5 gal) containers. Death appeared imminent for larger plants, since second-season growth was low and visual ratings were poor. Their study focused not only on container size but exposure, with western-facing plants having a higher mortality rate. Mortality rate was also higher in the smallest plants [1 liter (1 qt)] and was attributed to inadequate irrigation.

The objectives of this research were to: 1) determine if transplanting mountain laurel grown in a smaller container improves establishment compared to the traditional larger size and 2) determine if fall transplanting improves establishment compared to traditional spring transplanting. Two experiments were conducted. Experiment one tested fall vs. spring transplanting with 7.6 liter (2 gal) and 19 liter (5 gal) container-grown shrubs. Experiment two utilized root observation chambers (rhizotrons) to determine when fall- and spring-planted 19 liter (5 gal) shrubs began root growth and how far new roots grew into the backfill during the first post-transplant season.

## Materials and Methods

*Container size and transplant season*. Mountain laurel plants in 7.6 liter (2 gal) and 19 liter (5 gal) containers were obtained from Historyland Nursery (Warsaw, VA). Twelve of each size were transplanted into Groseclose silt loam soil (clayey, mixed, mesic Typic Hapludults; pH = 6.2) on October 6, 2000, at the Virginia Tech Urban Horticulture Center in Blacksburg, VA. Twelve of each size were held in an unheated greenhouse structure covered with 0.15 mm-thick (6 mil) white polyethylene (typical for overwintering nursery stock in Virginia) until planting on May 30, 2001. The bed was tilled to a 20 cm (8 in) depth prior to planting, and existing soil was used as backfill. The tops of the rootballs were ≈1 cm (0.5 in) above the surface of the backfill-soil. Plants were transplanted into 2 rows, 1 m (3.3 ft) between plants and rows. This study was a completely random experimental design and consisted of four treatments with 12 replications: (1) fall transplanted, 7.6 liter (2 gal) (F2); (2) fall transplanted, 19 liter (5 gal) (F5); (3) spring transplanted, 7.6 liter (2 gal) (S2); (4) spring transplanted, 19 liter (5 gal) (S5). The study area, including tops of rootballs, was mulched with a 5 cm (2 in) thick layer of coarse hardwood mulch after fall planting. Plants were hand-irrigated to field capacity ≈ every three days the first three weeks after transplanting and irrigated once a week (except as discussed below) starting in the spring with individual micro-emitters. Initial canopy volume for each plant was calculated as the product of the height and width in two directions (in row and perpendicular). Initial canopy volumes (SE in parentheses) were 0.11 (0.007) $m^3$ [3.91 (0.23) $ft^3$ ] and 0.29 (0.02) $m^3$ [10.36 (0.59) $ft^3$ ] for 7.6 liter (1 gal) and 19-liter (5 gal) plants, respectively.

On May 30, 2001, all plants were fertilized with a controlled release fertilizer (18N–2.6P–9.9K, Osmocote, The Scotts Co., Maryville, OH). F2 and S2 plants received 29 g (1 oz) each and the F5 and S5 plants received 81 g (2.9 oz) each. Rootball volumetric moisture was taken periodically (May 30, May 31, June 11, June 12, July 2, and July 3) for ≈ five weeks after spring planting (Theta Meter, Type HH1, Dynamax, Inc., Houston, TX). Rootball volumetric water content values were corrected from the organic substrate setting on the Theta Meter as a calibration (6) with 100% pinebark (actual = 0.1748 + 0.5269 (measured), $r^2$ = 0.85). The Theta Probe uses time domain reflectometry (1) to measure the average volumetric water content from the top to the bottom of the 6 cm (2.5 in) long metal probes and the substrate surrounding the probes.

Leaf water potential (Ψ) was measured with a Scholander pressure chamber (Soil Moisture Equipment Corporation, Santa Barbara, CA) for three, 12-hour periods, spaced a week apart, during September 2001. No irrigation was applied during this period, and no rainfall event was recorded. For a 12-hour period, plants were measured at 2-hour intervals, from 0700 to 1900 hours. Two recently mature leaves (3 to 5 leaves from twig tip) from each of three randomly selected plants per treatment were selected from separate twigs located on the southwest facing side of the plant, midway in the plant canopy height. Leaves were removed at the base of the petiole. The two leaves from each plant were averaged as Ψ for that replication. The integrated daily leaf xylem potential (17) (I-Ψ) was calculated for each replication using SigmaPlot computer software.

On November 6, 2001, October 7, 2002, and July 10, 2003 all plants were rated with a visual rating index (VRI), consisting of leaf color, proportion of leaf spot (*Cercospora kalmiae*), and fullness of canopy. For the VRI, each of the three categories consisted of a scale from 1 to 5. For leaf color, a 1 represented a chlorotic plant and a 5 represented a dark green plant. For proportion of leaf spot, a 1 represented a plant that had a very high proportion of leaf spot and a 5 represented a plant with essentially no leaf spot. For fullness of canopy, a 1 represented a very dense canopy and a 5 represented a very sparse canopy. Four independent observers rated each plant for the three categories. A composite VRI for each plant was calculated to be the mean of the VRI for each of the three categories and averaged over the four observations.

On November 6, 2001, six plants from each treatment were randomly chosen and harvested. Each plant was severed at the top of the rootball and stems and leaves were separated. Stems and leaves were dried to a constant weight at 70C (158F), and the leaf area of a sub-sample from each treatment were measured (LI1600; LI-COR, Lincoln, NE). Leaf area measurements consisted of 50 randomly selected leaves per treatment. Total leaf area was calculated by multiplying total dry weight of leaves by the mean leaf area:dry weight of the 50-leaf subsample. All data were subjected to analysis of variance with the GLM procedure of SAS (SAS, ver 8.02, SAS Institute, Cary, NC).

*Rhizotron root growth study*. On October 6, 2000, four, 19 liter (5 gal) mountain laurel (described above) were transplanted into four aboveground rhizotrons at the Urban Horticulture Center. Rhizotrons were constructed from Keeper-Uppers (KU) (Lerio Corp., Kissimmee, FL), measuring 53 cm (21 in) length × 54 cm (21 in) width × 38 cm (15 in) height, with the top opening at 43 cm (17 in) diameter. A polycarbonate window was installed on one side of each rhizotron. Plastic bubble insulation with a reflective coating (Reflectix Insulation, Reflectix Inc., Markleville, IN) was wrapped around the rhizotrons, maintaining a comparable temperature with the soil in the bed (data not shown). A 5 cm (2 in) thick piece of plastic foam covered each of the windows, and was held in place by two stretch cords. Four additional plants were stored as described above and planted into rhizotrons on May 30, 2001. Rhizotrons were in a single row, spaced approximately 1 m (3.3 ft) on center. This study was

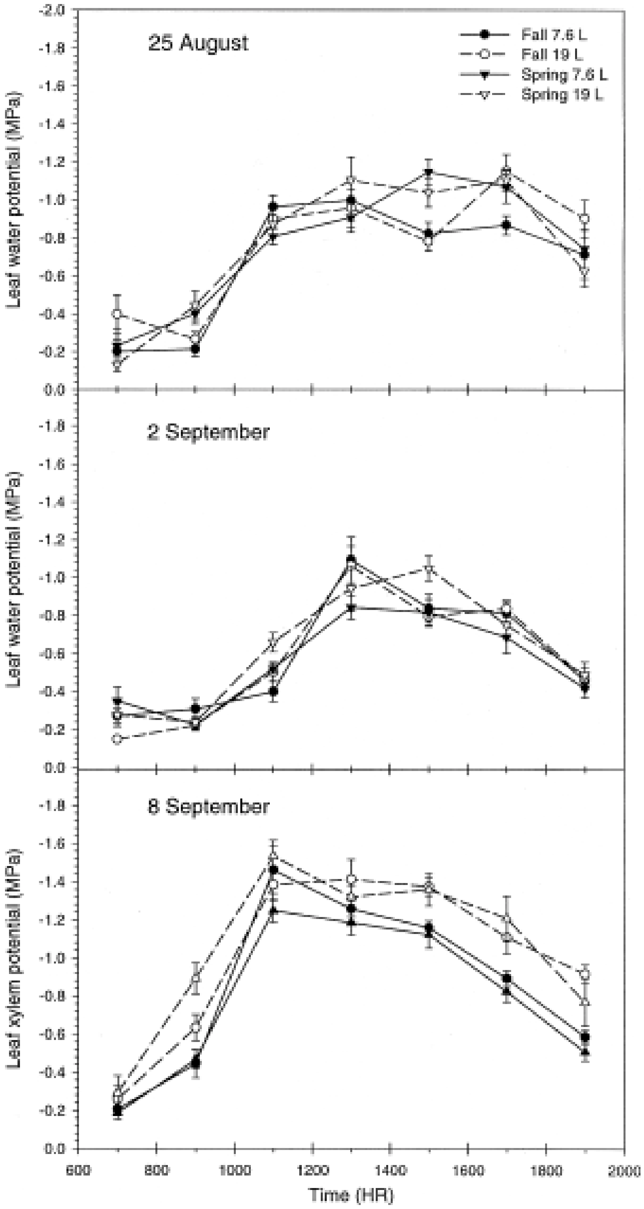


**Fig. 1. Daily patterns of leaf xylem potential for the beginning, middle, and end of a 15-day drying cycle for mountain laurel shrubs transplanted in fall or spring and from 7.6 liter (2 gal) or 19 liter (5 gal) containers. Each data point is the mean of 3 replications (2 subsamples per replication). Bars represent ± SE.**

a completely random experimental design, with four replications of two treatments: fall transplanted, and spring transplanted. Rootballs were oriented at an angle parallel to rhizotron windows, and the rhizotron substrate was 100% pinebark. Coarse hardwood mulch was applied in a 5 cm (2 in) layer over the rootball surface. All plants were hand-irrigated on alternate days for three weeks after transplanting. A micro-emitter irrigation system was installed in mid May 2001. All plants were irrigated twice weekly thereafter to apparent field capacity.

On May 30, 2001, the remaining four plants (overwintered and irrigated in a polyhouse at the Urban Horticulture Center) were transplanted into the last four rhizotrons. All eight plants were fertilized with 81g (2.9 oz) of slow-release fertilizer (18N–2.6P–9.9K, Osmocote, The Scotts Co., Maryville, OH). Newly transplanted shrubs were hand-irrigated for a week and then put on the same irrigation system as stated above. Each rhizotron was checked periodically for the presence of new root growth.

On November 6, 2001, canopy volumes were measured as described for experiment one and rhizotrons were removed. Pinebark substrate was gently removed from each rootball, leaving all roots intact. Roots from the window side of the rootball were gently stretched and the lengths of the four longest roots were measured. The longest measurement was excluded and the remaining three were averaged together to be the maximum root extension for that plant. Data were subjected to analysis of variance with the GLM procedure of SAS.

## Results and Discussion

*Container size and transplant season. Leaf xylem potential.* Treatment effects on leaf xylem potential were not evident when measured on August 25 (Fig. 1, Table 1). However, drying conditions began to affect treatments on September 2, with S5 plants being more stressed (more negative I-Ψ) than S2 plants. Fall-transplanted treatments were similar to each other. As drying continued and measurements were made on September 8, 19 liter (5 gal) plants were more stressed than 7.6 liter (2 gal) plants for fall and spring transplants, with transplant season having little effect on I-Ψ.

Effect of container size on transplant response may be partly due to container size characteristics. Rootball surface area to rootball volume ratio was calculated to be 0.23 and 0.18 for 7.6 liter (2 gal) and 19 liter (5 gal) plants, respectively. This higher ratio for 7.6 liter (2 gal) plants should favor root growth into backfill soil for these plants vs. the 19 liter (5 gal) plants because a higher percentage of the rootball is exposed to the backfill-soil. In addition to the more favorable interface area per unit rootball volume for 7.6 liter (2 gal) plants, leaf area index (LAI) (total leaf area divided by the product of two perpendicular canopy widths) values were also more favorable. Mean LAI for 7.6 liter (2 gal) plants and 19 liter (5 gal) plants were 1.31 and 3.18, respectively when harvested on November 6, 2001. Canopies of 19 liter (5 gal) plants were therefore denser, likely increasing rootball

**Table 1. Effect of fall vs. spring transplanting and 7.6 liter (2 gal) vs. 19 liter (5 gal) production container size on integrated daily leaf xylem potential (I-Ψ) of *Kalmia latifolia* L. 'Olympic Wedding' during a drying interval the first summer after transplanting.[z]**

| | Aug 25 | Sept 2 | Sept 8 |
|---|---|---|---|
| | | P > F[y] | |
| Container | 0.628 | 0.164 | 0.007 |
| Season[x] | 0.441 | 0.855 | 0.927 |
| Container × season | 0.869 | 0.068 | 0.317 |
| Fall 7.6 liter vs.19 liter | NA | 0.694 | NA |
| Spring 7.6 liter vs. 19 liter | NA | 0.033 | NA |

[z]See Fig. 1 for graphical presentation of data. I-Ψ of each replication represents the area under of the curve of each replication.

[y]P > F from analysis of variance.

[x]Plants were either planted on October 6, 2000 (Fall) or May 30, 2001 (Spring).

Table 2. **Effect of fall vs. spring and 7.6 liter (2 gal) vs. 19 liter (5 gal) production container size on volumetric water content of rootballs of *Kalmia latifolia* L. 'Olympic Wedding' during the first post-transplant season. (N = 11)**

| | | Volumetric water content ($m^3 \cdot m^{-3}$) | | | | | |
|---|---|---|---|---|---|---|---|
| **Container size** | **Season** | **May 30** | **May 31** | **June 11** | **June 12** | **July 2** | **July 3** |
| 7.6 liter (F2) | Fall | 0.371 | 0.353 | 0.341 | 0.315 | 0.322 | 0.293 |
| 7.6 liter (S2) | Spring | 0.395 | 0.339 | 0.340 | 0.299 | 0.311 | 0.290 |
| 19 liter (F5) | Fall | 0.350 | 0.285 | 0.290 | 0.246 | 0.290 | 0.249 |
| 19 liter (S5) | Spring | 0.354 | 0.308 | 0.295 | 0.245 | 0.253 | 0.220 |
| | | **P > F** | | | | | |
| Container | | 0.001 | 0.001 | 0.001 | 0.001 | 0.004 | 0.001 |
| Season | | 0.072 | 0.620 | 0.860 | 0.460 | 0.11 | 0.25 |
| Container × season | | 0.199 | 0.021 | 0.820 | 0.530 | 0.36 | 0.38 |

[z]Volumetrtic moisture content for top 6 cm (2.5 in) of rootballs. All plants were irrigated before measurement on May 30 and on June 6, 13, 20, and 27.

[y]P > F from analysis of variance.



water loss from transpiration. Compared to 7.6 liter (2 gal) rootballs, 19 liter (5 gal) rootballs consistently contained lower volumetric water content early in the first post-transplant growing season (Table 2). Rootball volume to leaf surface area ratio was 4.76 and 2.27 for 7.6 liter (2 gal) and 19 liter (5 gal) plants, respectively, further emphasizing that 19 liter (5 gal) plants had a relatively smaller water supply to support transpiration.

*Canopy growth*. Little evidence exists for a treatment effect on % canopy volume increase until 2003 (Table 3), when canopies of 7.6 liter (2 gal) plants had greater % increase than those of 19 liter (5 gal) shrubs (p = 0.073). Our data differ from that of Wright et al. (23), who found in an exposure study on mountain laurel that 7.6 liter (2 gal) plants had more shoot growth than 19 liter (5 gal) plants for a two-year period, in that we did not see strong evidence for more growth of the smaller plants until three years after transplanting. Reports on the effect of transplant season on post-transplant growth of other species have mixed results. Fall planting is reported to increase post-transplant growth compared to spring transplanting by some (3, 22), to decrease growth compared to spring transplanting by others (7, 20), or to have no affect on post-transplant growth (11, 21). These conflicting results are probably due to genotype X environment interactions, such as was evident between our study and that by Wright et al. discussed above.

Table 3. **Effect of fall vs. spring transplanting and 7.6 liter (2 gal) vs. 19 liter (5 gal) production container size on % canopy increase of *Kalmia latifolia* L. 'Olympic Wedding' for three growing seasons after transplanting. (N = 11 for 2001, 4 for 2002, and 4 for 2003).**

| | | % increase[y] | | |
|---|---|---|---|---|
| **Container size** | **Season[z]** | **2001** | **2002** | **2003** |
| 7.6 liter (F2) | Fall | 9.34 | 19.34 | 53.57 |
| 7.6 liter (S2) | Spring | 22.80 | 38.59 | 53.25 |
| 19 liter (F5) | Fall | 5.66 | 28.12 | 29.94 |
| 19 liter (S5) | Spring | 6.27 | 11.27 | 18.72 |
| | | **P > F** | | |
| Container | | 0.185 | 0.157 | 0.073 |
| Season | | 0.353 | 0.361 | 0.704 |
| Container × season | | 0.340 | 0.719 | 0.719 |

[z]Plants were either planted on October 6, 2000 (Fall) or May 30, 2001 (Spring).

[y]Cumulative least square mean for % increase in canopy volume. Beginning measurements were made on May 31 for fall and June 6 for spring transplants. Plants were either planted on October 6, 2000 (Fall) or May 30, 2001 (Spring).

One growing season after transplanting, spring-transplanted shrubs had greater leaf dry weight than fall transplants (p = 0.058) and S5 plants had more leaf area than F5 plants (p = 0.001) (Table 4). Transplant season did not affect stem dry weight (p = 0.447). Fall transplants were exposed to winter conditions, whereas spring transplants were protected and began shoot growth before they were transplanted on May 30. Increased leaf area without an accompanying extension of roots into the backfill-soil is potentially detrimental if adequate irrigation is not applied directly to rootballs since the increased transpiration can very quickly result in substrate water deficit.

*Visual rating index*. At the end of the first growing season, 19 liter (5 gal) plants had the highest visual rating index (fuller canopy, darker leaves, and less leaf spot) (Table 5). However, no treatment effect was evident for 2002. In 2003, F5 plants had higher ratings than F2 plants, but reversed results were evident for spring transplants. In hotter and drier climates, container size may override seasonal effects, and production size may not interact with transplant season. Visual rating of container-grown mountain laurel in Raleigh, NC (USDA plant hardiness zone 7b), compared to Blacksburg, VA (USDA plant hardiness zone 6A), indicated that 7.6 liter (2 gal) plants looked better than 19 liter (5 gal) plants after two growing seasons (23).

*Rhizotron root growth study*. Root extension for fall-transplanted mountain laurel was first observed in mid-April in the rhizotrons, approximately six weeks before spring transplants were planted. The spring transplanting date (May 30) coincided with full bloom, the time when mountain laurels are traditionally sold in garden centers and planted in Virginia. Root extension for spring transplants was first noticed three weeks after transplanting. Landscapers can therefore get a considerable head start (nine weeks in our study) on post-transplant root growth by planting in fall vs. the traditional spring date. Mean root extension into the backfill soil

Table 4. **Effect of fall vs. spring transplanting and 7.6 liter (2 gal) vs. 19 liter (5 gal) production container size on leaf and stem dry weight and leaf area of *Kalmia latifolia* L. 'Olympic Wedding' one growing season after transplanting.**

| Container size | Season[z] | Leaf dry weight (g) | Stem dry weight (g) | Leaf area ($cm^2$) |
|---|---|---|---|---|
| 7.6 liter (F2) | Fall | 60.8 | 87.5 | 2867.1 |
| 7.6 liter (S2) | Spring | 76.4 | 84.5 | 3279.0 |
| 19 liter (F5) | Fall | 162.7 | 260.7 | 6328.8 |
| 19 liter (S5) | Spring | 186.0 | 280.9 | 8772.8 |
| | | | P > F[y] | |
| Container | | 0.001 | 0.001 | 0.001 |
| Season | | 0.058 | 0.447 | 0.003 |
| Container × season | | 0.695 | 0.305 | 0.028 |
| Fall 7.6 liter vs. Spring 7.6 liter | | NA | NA | 0.503 |
| Fall 19 liter vs. Spring 19 liter | | NA | NA | 0.001 |

[z]Plants were either planted on October 6, 2000 (Fall) or May 30, 2001 (Spring).

[y]P > F from analysis of variance.



was longer on November 6 (P = 0.002) for fall transplants [13.8 cm (5.4 in)] than spring transplants [9.2 cm (3.6 in)]. While these numbers seem small compared to root extension for other landscape plants (e.g., 10), it may represent the potential for the species. Casual observation of root extension into the backfill soil when plants were excavated in 2001 for experiment one (field) plants revealed little root growth into the backfill soil. Roots appeared to be actively growing within the rootballs, highlighting the need to irrigate directly on the rootballs of mountain laurel the first season after transplanting. Excavation in July 2003 revealed more root extension than in 2001, but growth was sporadic, with no apparent treatment effect. In contrast to shrubs transplanted to field beds, plants in rhizotrons had relatively good extension into the backfill. Rhizotron plants were irrigated more often and had a different backfill (pine bark vs. native soil) with a lower pH (6.2 for soil and 4.3 for pinebark), possibly creating environment more conducive to root growth compared to the native soil used for the field-grown plants. The pH of the backfill-soil in experiment one was tested at the end of the 3-year experiment and there was a slight increase from 6.2 to 6.5 during the three-year study, presumably from mulching with hardwood mulch. There is evidence that mountain laurel seedlings grow better in soil beds amended with organic material, but strong evidence for transplanting larger plants into beds amended with organic matter is lacking (2).

Table 5. **Effect of fall vs. spring transplanting and 7.6 liter (2 gal) vs. 19 liter (5 gal) production container size on visual ratings of *Kalmia latifolia* L. 'Olympic Wedding' for three growing seasons after transplanting.**

| | | Visual index rating[z] | | |
|---|---|---|---|---|
| Container size | Season | 2001 | 2002 | 2003 |
| 7.6 liter (F2) | Fall | 2.95 | 3.27 | 2.77 |
| 7.6 liter (S2) | Spring | 3.21 | 3.20 | 2.83 |
| 19 liter (F5) | Fall | 3.92 | 3.20 | 3.31 |
| 19 liter (S5) | Spring | 3.76 | 2.85 | 2.33 |
| | | | P > F[y] | |
| Container | | 0.001 | 0.245 | 0.916 |
| Season | | 0.718 | 0.242 | 0.016 |
| Container × season | | 0.162 | 0.427 | 0.007 |
| Fall 7.6 liter vs. 19 liter | | NA | NA | 0.046 |
| Spring 7.6 liter vs. 19 L | | NA | NA | 0.064 |

[z]All plants were rated by 5 people. Mean ratings are composite of separate visual ratings of 1–5 (5 = best) each for color, leaf spot, and fullness. Ratings were made in October 2001 and 2002 and July 2003. N = 11 for 2001 ratings and N = 4 for 2002 and 2003 ratings.

[y]P > F from analysis of variance.

While root extension was longer in fall- vs. spring-transplanted shrubs in rhizotrons, canopy volume increase was 0.015 $m^3$ (0.539 $ft^3$) for fall and 0.077 $m^3$ (2.72 $ft^3$) for fall- and spring-transplanted shrubs, respectively. Smaller first-season canopy growth of fall transplants (P = 0.037) was likely due to the fact that fall transplants were exposed to ambient conditions, whereas spring transplants were protected in unheated, but covered, greenhouses. Cold winter winds can potentially desiccate foliage of fall transplants, especially since root growth into the backfill does not begin until spring. Fall transplanting in exposed areas where winter soils are consistently frozen and winds are strong may not be prudent. In addition to winter protection, the warm early spring temperatures in the overwintering structure likely facilitated nutrient uptake and growth for spring transplants. However, increased canopy growth of spring transplants before new root growth into the backfill would make diligent irrigation of these transplants even more critical since rootballs would dry out more quickly and denser canopies would increase the likelihood of shielding rootballs from overhead irrigation or rain. The reduced post-transplant canopy growth and earlier and longer root extension into the backfill soil of fall transplants should enhance potential for establishment since an increased capacity for water absorption and a reduced capacity for transpiration would increase resistance to post-transplant water stress.

In conclusion, our data generally support planting 7.6 liter (2 gal) size mountain laurel vs. 19 liter (5 gal) plants and fall vs. spring planting for best results. Canopies of 7.6 liter (2 gal) shrubs appeared to be catching up with those of the larger 19 liter (5 gal) shrubs (Table 3). However, the best evidence for an advantage to fall vs. late spring transplanting comes from the fact that fall transplants in rhizotrons had longer root extension into the backfill soil than spring transplants at the end of the first season after transplanting.

The main difficulty in getting container-grown mountain laurel to quickly establish in landscapes is probably the relatively short root extension into backfill-soil the first season after transplanting. Even under the best conditions (e.g., the plants in rhizotrons), root extension is limited compared to other landscape plants. Future research should concentrate on the edaphic characteristics required for best root extension. A backfill environment tailored for mountain laurel establishment, along with fall planting of smaller plants, may yield the best results.

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