Evaluation of Twenty-one Mountain Laurel Cultivars for Container and Landscape Performance in the Southeastern United States

He Li, Matthew Chappell, and Donglin Zhang¹

ADDITIONAL INDEX WORDS. *Kalmia latifolia*, growth index, morphology, performance rating, maximum quantum yield, stress tolerance

SUMMARY. Mountain laurel (*Kalmia latifolia*) is an outstanding ornamental shrub due to its attractive foliage and showy inflorescences. Breeding efforts have led to improved selections that have predominantly been developed and evaluated in the northeastern United States. Consequently, most cultivars have largely been dismissed as incompatible for the southeastern U.S. environmental conditions by nursery growers and consumers. This study was conducted over a 4-year period to evaluate 21 popular mountain laurel cultivars, primarily developed in the northeastern United States, for container and field performance in Georgia. All cultivars yielded considerable growth in the first year of container trials, indicating production of mountain laurel as a 1-year container crop is feasible. Cultivars displayed significantly different total growth index throughout the container trial. Fast-growing cultivars such as Bullseye and Ostbo Red yielded more than 100, 150, and 250 cm of growth index in 1, 2, and 4 years, respectively. Conversely, cultivars that grew slower, such as Firecracker and Tinkerbell, had less than 80, 115, and 180 cm in 1, 2, and 4 years, respectively. Cultivars were classified into five groups, using principal component analysis, that included dwarf habit with pink flower, dwarf habit with nonpink flower, nondwarf habit with green stem and white flower, nondwarf habit with pigment-patterned flower, and nondwarf habit with pink flower. In a field study, performance rating of 21 cultivars ranged from 2.0 to 4.8 (out of 5.0) in 2014 and from 2.0 to 5.0 in 2015. Ten cultivars that received the highest ratings over these 2 years were selected for a subsequent field trial in 2016. Cultivars showed overall decreased ratings (1.0–3.3) from the previous 2 years because of late spring planting. ‘Ostbo Red’, ‘Pristine’, and ‘Tinkerbell’ had higher performance ratings, more net growth, and less decrease in maximum quantum yield, which indicated suitable adaptation to southeastern U.S. environmental conditions. Nursery growers and consumers should benefit from regional cultivar trial information derived from this study. ‘Ostbo Red’, ‘Pristine’, and ‘Tinkerbell’ performed well across trials and therefore are recommended for southeastern U.S. landscapes based on superior container and field performance, leaf spot (caused by *Mycosphaerella colorata*) tolerance, and morphologic distinctions.

Mountain laurel is an ever-green flowering shrub in the heath family (*Ericaceae*) that occurs throughout temperate areas of the world (Jaynes, 1988). Mountain laurel is native to the eastern United States, specifically from southern Maine west through southern New York to central Ohio, south to eastern Louisiana, southern Mississippi, Alabama, Georgia, and northwestern Florida (Kurmes, 1967). The plant has been considered by many horticulturists, nursery growers, and gardeners to be an outstanding flowering native species (Dirr, 2009; Jaynes, 1988). Its attractive, lustrous green

foliage; showy inflorescences; and variations in morphological traits have made mountain laurel a valuable ornamental shrub in the nursery and landscape industries (Jaynes, 1988).

Many cultivars of mountain laurel have been introduced into the marketplace, beginning in the early 1960s (European *Kalmia* Society, 2018). Yet there is still considerable uncertainty about these plants and their performance in areas south of U.S. Department of Agriculture

(USDA) Zone 7, particularly in the southeastern United States. In the southeastern United States, few cultivars are available in retail settings and those cultivars that are produced are principally done so by niche, heath-family nurseries. Ironically, although produced in several southeastern U.S. nurseries, mountain laurel is rarely used in southeastern U.S. landscapes (Jaynes, 1988). The majority of mountain laurel cultivars were evaluated (before release) and selected for release in the northeastern United States. As a result, the performance of cultivars outside the northeastern United States is relatively unknown, which has historically limited cultivar acceptance in other regions of the United States (Jaynes, 1982, 1988). An example of this regionality in cultivar development and use is ‘Sarah’, selected by R.A. Jaynes at the Connecticut Agricultural Experiment Station. Although well adapted to northeastern U.S. landscapes, no documentation exists regarding its broader adaptability due to a lack of evaluation outside the northeastern United States.

Southeastern U.S. climate varies significantly from that of the Northeast. Milder winter temperatures lead to less cold damage in nurseries and landscapes of the southeastern United States. Yet hotter and more humid summer conditions, as well as a lack of winter chilling hours, could limit adaptability of cultivars selected in the Northeast and transitioned into southeastern U.S. nurseries and landscapes. Limited information on physiological and adaptive responses, including heat tolerance, photosynthetically active radiation tolerance, growth rates, disease and insect tolerance, required chilling hours to flower, soil moisture tolerance, for example, for most of mountain laurel cultivars is available (Jaynes, 1982, 1988). Additionally, although phenotypic traits of many mountain laurel cultivars have been well described at the time of release, these traits may differ across drastically different physiographic

Department of Horticulture, University of Georgia, 1111 Miller Plant Sciences Building, Athens, GA 30602

¹Corresponding author. E-mail: donglin@uga.edu.
<https://doi.org/10.21273/HORTTECH04174-18>

Units			
To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
0.3048	ft	m	3.2808
3.7854	gal	L	0.2642
2.54	inch(es)	cm	0.3937
1.6093	mile(s)	km	0.6214
28.3495	oz	g	0.0353

regions (Jaynes, 1988) due to genotype by environment interactions (Schlichting, 1986). This phenotypic variability was documented to occur in inkberry (*Ilex glabra*), whereby leaf traits varied when grown in varying environments (Givnish, 1984). This study evaluated 21 popular mountain laurel cultivars for their potential as both nursery and landscape plants. Our objectives were to provide comprehensive regional cultivar information for growers, landscape contractors, and breeders that could enhance mountain laurel production and landscape performance by identifying those cultivars with greatest adaptability to the southeastern United States.

Materials and methods

PLANT MATERIALS. Liners of 21 cultivars were commercially

micropropagated, rooted, and shipped from Briggs Nursery, Inc. (Elma, WA) to the University of Georgia Durham Horticulture Farm (UGA Hort Farm) in Watkinsville, GA [lat. 33.88689°N, long. 83.41941°W, 236 ft elevation, USDA Zone 8a (USDA, 2012)] on 11 Mar. 2013 in 49-cell flats. These cultivars were selected based on their popularity, reported superior landscape performance, and their diversity in habit, foliage, and inflorescence in the northeastern United States (Fig. 1). Liners (8–10 cm tall, 5–6 cm wide) were immediately transplanted into 1-gal containers (PF310; Nursery Supplies, Chambersburg, PA) filled with pine bark-based soilless substrate (85% bark pine, 15% compost; Sun Gro Horticulture, Agawam, MA). Potted plants were top-dressed with

5 g of 20N–1.3P–7.5K controlled-release fertilizer (Everris, Marysville, OH). Containers were held in an unheated coldframe covered with 60% shade cloth and irrigated twice per day (15 min per irrigation event) using 10-ft full-circle nozzles (Rain Bird, Azusa, CA) monitored by a timer (Node-100; Hunter, San Marcos, CA) until container and field trials were initiated.

CONTAINER EVALUATION. Container performance was assessed at the UGA Hort Farm beginning on 4 May 2013. On 21 May 2015, the plants were transplanted from 1- to 3-gal containers (PF1200; Nursery Supplies) filled with bark-based substrate as described previously and fertilized with 15 g of 20N–1.3P–7.5K controlled-release fertilizer (Everris). Plants were maintained in

'Pristine'

'Sarah'

'Nathan Hale'

'Peppermint'

'Kaleidoscope'

'Pink Charm'

'Red Bandit'

'Bullseye'

'Ostbo Red'

Fig. 1. Diversity in size, shape, color, and pigment pattern of flowers among popular mountain laurel cultivars.

the same shade-house as described earlier for continued evaluation as 3-gal containers through the end of the trial in 2017 and top-dressed with 20N-1.3P-7.5K controlled-release fertilizer (Everris) annually.

Total growth index measurements were taken in the first week of May 2014, 2015, and 2017. Measurements included height (ground level to the tallest point), width at the widest point, and width perpendicular to the widest point. Growth index was then calculated as height + width 1 + width 2. Morphological traits were observed on container-grown plants throughout the container trial. Morphological measurements were taken on 11 traits that described habit, flowering, and leaf characteristics. Traits described by Jaynes (1988) that are responsible for major variations among cultivars were documented. These are described in Table 1 and included habit, stem and petiole color, leaf size, leaf blade, leaf surface, leaf color, flower size, bud color, corolla color, pigment pattern, and bloom time. Size measurements, including flower and leaf size, were taken on three flowers in full bloom and three mature leaves on each plant. Additionally, leaf spot incidence was recorded, but severity was not assessed.

FIELD TRIAL. The first field trial was conducted at the UGA Hort Farm from 2013 to 2015. Four 1-gal containerized plants of the same 21 cultivars evaluated in containers

were transplanted to the field on 1 Oct. 2013. The planting bed was tilled to a 10-inch depth before planting and existing Cecil clay soil (unamended) was used as backfill into planting holes. The trial was divided into four replications (rows), and one plant of each cultivar was randomly assigned to each replication. Plants were transplanted on 6-ft centers. The root balls were slightly split and then covered with backfill-soil. Plants were top-dressed with 15 g of 20N-1.3P-7.5K controlled-release fertilizer (Everris), and then beds were mulched with a 2-inch-thick layer of pine straw. Plants were watered using drip irrigation with emitters [2 gal/h (XB20PC, Rain Bird)] immediately after planting and then watered as needed by manually turning on and off an irrigation valve. Plant performance rating was evaluated on 8 Oct. 2014 and 7 Oct. 2015. The performance rating was made using a scale of 1 (dead) to 5 (excellent: vigorous growth, lush and green foliage, no leaf spot, and no above-ground damage), based on overall plant size and vigor, leaf color, incidence of leaf spot, and leaf and shoot damage due to abiotic conditions.

On the basis of the results of 2014 and 2015 field trial, 2-year-old 1-gal container plants of the highest rated 10 cultivars were planted in a field plot in the same manner as described earlier at the UGA Riverbend Research Center in Athens, GA [lat. 33.93014°N, long. 83.36364°W,

670 ft elevation, USDA Zone 8a (USDA, 2012)] on 14 Apr. 2016. Four replications were installed, each with one plant of each cultivar randomized within replication. Plants were installed in unamended Cecil clay field soil on 6-ft centers within two cultivated rows tilled to a depth of 10 inches. Light energy absorbed by chlorophyll in a leaf undergoes three fates: being used to drive photosynthesis, being emitted as heat, and being re-emitted as chlorophyll fluorescence. The spectrum of chlorophyll fluorescence is different from that of absorbed light. As a result, the yield of chlorophyll fluorescence can be measured and this information served as an indication of photosynthetic efficiency. Maximum quantum yield of photosystem II (F_v/F_m) is calculated as $(F_m - F_0)/F_m$, where F_m and F_0 indicate maximum and minimal level of fluorescence, respectively. F_v/F_m has been used as a determination of damage to photosystem II due to abiotic (e.g., heat and light) stress (Baker and Rosenquist, 2004; Maxwell and Johnson, 2000). This study quantified decreases in F_v/F_m over the course of a growing season to determine abiotic stress tolerance of cultivars in the 2016 field study. F_v/F_m was measured on three leaves of each plant beginning at dawn and ending at sunrise using a portable fluorometer (FluorPen FP 100; Photon Systems Instruments, Albuquerque, NM). Baseline F_v/F_m and growth index were recorded while plants were in

Table 1. Eleven morphologic characters describing habit, flowering, and leaf characteristics observed on 21 mountain laurel cultivars for morphological measurements.

Character	Numerical description ^a				
	0	1	2	3	4
Habit	Sparse and dwarf	Dense and dwarf	Sparse and typical	Dense and typical	
Stem and petiole color	Green	Slightly purplish red	Moderately purplish red	Purplish red	
Leaf size	Length + width <5 cm	5 cm < length + width < 8 cm	Length + width >8 cm		
Leaf blade	Elliptic	Elliptic to ovate	Elliptic to lanceolate	Lanceolate	Lanceolate to ovate
Leaf surface	Flat	V-shaped	Cupped	Wavy	
Leaf color	Medium green	Medium to dark green	Dark green		
Flower size	Diameter < 1.8 cm	1.8 cm < diameter < 2.5 cm	Diameter > 2.5 cm		
Bud color	White	Light pink	Pink	Deep pink	Red
Corolla color	White	Light pink	Pink	Deep pink	
Pigment pattern	No pigment	Normal band	Full band	Radiation	Spot
Bloom time	Before 1 May	Between 1 and 15 May	After 15 May		

^aSize measurements, including leaf and flower size, were taken on three mature leaves and three flowers in full bloom on each plant; 1 cm = 0.3937 inch.

containers, the day before cultivars were planted (13 Apr. 2016). Final growth index and F_v/F_m were measured on plants in field plots on 9 Nov. 2016. Net growth was then calculated as final growth index – initial growth index. The percentage of decrease in F_v/F_m was calculated as $[(\text{initial } F_v/F_m - \text{final } F_v/F_m)/\text{initial } F_v/F_m \times 100\%]$. Plant performance ratings were collected using the same 1 to 5 scale as described in the first field trial.

EXPERIMENTAL DESIGN AND DATA ANALYSIS. Experimental design for the container evaluation study was a completely randomized design with four replications. Each replication included one plant of 21 cultivars. Likewise, randomized complete block design was employed for the field trial, which included four replications with one plant of each cultivar per replication. Growth index, net growth, performance rating, and the percentage change in F_v/F_m were subjected to analysis of variance using GLM procedures in SAS (University Edition; SAS Institute, Cary, NC). Fisher's least significant difference at $P < 0.05$ was applied for mean separation. Principal component analysis (PCA) was performed on morphological traits using SPSS (version 21.0; IBM Corp, Armonk, NY). The first two axes were plotted according to the extracted Eigen vectors in Excel (Microsoft, Redmond, WA).

Results and discussion

CONTAINER EVALUATION. Twenty-one container-grown mountain laurel cultivars reached 60 cm or greater total growth in the first year (2013–14). At this size, plants would be marketable after a 1-year production cycle, indicating it is feasible to commercially produce mountain laurel as container plants in the southeastern United States. Yet cultivars displayed differences in plant size during container evaluation (Table 2). In 2014, 'Bullseye', 'Forever Red', 'Freckles', 'Heart of Fire', 'Olympic Fire', 'Ostbo Red', and 'Pink Charm' had growth indices of ≥ 100 cm (Table 3). These large cultivars continued vigorous growth rates in containers after 2 years of production in 2015 (≥ 145 cm) and 4 years of production in 2017 (≥ 230 cm). 'Carol' and 'Peppermint' showed similar

Table 2. Analysis of variance table for growth index of 21 mountain laurel cultivars in container evaluation; performance rating of 21 cultivars in 2014 and 2015 field trial; and performance rating, net growth, and decrease in F_v/F_m of 10 cultivars in 2016 field trial.^z

Source	df	Mean square	F	P
Container evaluation				
Cultivar				
2014 growth index	20	622.8	7.1	<0.0001
2015 growth index	20	2,277.7	7.1	<0.0001
2017 growth index	20	5,929.3	9.3	<0.0001
2014 and 2015 Field trial				
Cultivar				
2014 performance rating	20	2.5	1.83	0.0380
2015 performance rating	20	3.1	1.2	0.2987
2016 Field trial				
Cultivar				
Performance rating	9	2.2	1.1	0.4052
Net growth	9	425.1	1.4	0.2363
Decrease in F_v/F_m (%)	9	1,482.5	0.6	0.7914

^z F_v/F_m = maximum quantum yield. Decrease in F_v/F_m was calculated as $[(\text{initial } F_v/F_m - \text{final } F_v/F_m)/\text{initial } F_v/F_m \times 100\%]$.

Table 3. Growth index of container-grown plants of 21 mountain laurel cultivars at the University of Georgia Durham Horticulture Farm in Watkinsville, GA, after being grown for 1 (2014), 2 (2015), and 4 years (2017) (n = 4).

Cultivar	Growth index [mean $\pm$ SE (cm)] ^z		
	2014	2015 ^y	2017
Bullseye	100.1 $\pm$ 9.3 ab ^x	158.5 $\pm$ 12.4 abcde	301.2 $\pm$ 12.2 a
Carol	86.4 $\pm$ 3.4 cdef	154.0 $\pm$ 10.7 abcdef	251.6 $\pm$ 8.0 bcdef
Elf	86.4 $\pm$ 5.8 cdef	140.5 $\pm$ 15.5 cdef	227.2 $\pm$ 16.7 defgh
Firecracker	68.3 $\pm$ 1.2 hi	114.9 $\pm$ 6.6 ghij	164.9 $\pm$ 11.9 j
Forever Red	99.6 $\pm$ 1.4 abc	146.4 $\pm$ 16.6 abcdef	244.2 $\pm$ 18.7 bcdefg
Freckles	105.3 $\pm$ 3.8 a	160.2 $\pm$ 7.0 abcd	232.1 $\pm$ 19.9 cdefgh
Heart of Fire	100.7 $\pm$ 5.4 ab	168.5 $\pm$ 10.1 ab	275.3 $\pm$ 7.5 ab
Kaleidoscope	78.9 $\pm$ 2.6 efgh	110.2 $\pm$ 4.7 hij	175.1 $\pm$ 13.0 ij
Little Linda	88.4 $\pm$ 4.0 bcde	135.5 $\pm$ 4.7 defg	215.3 $\pm$ 9.1 gh
Minuet	74.5 $\pm$ 4.3 fghi	143.8 $\pm$ 2.8 bcdef	156.1 $\pm$ 5.3 j
Nathan Hale	62.3 $\pm$ 2.3 i	96.8 $\pm$ 7.0 j	213.6 $\pm$ 4.6 gh
Olympic Fire	99.4 $\pm$ 6.9 abc	171.1 $\pm$ 5.2 a	264.8 $\pm$ 14.2 bc
Ostbo Red	101.6 $\pm$ 3.4 ab	149.5 $\pm$ 6.9 abcdef	253.5 $\pm$ 4.0 bcde
Peppermint	97.0 $\pm$ 4.2 abcd	157.4 $\pm$ 7.2 abcde	270.5 $\pm$ 15.7 ab
Pink Charm	105.9 $\pm$ 7.4 a	164.2 $\pm$ 8.6 abc	229.9 $\pm$ 2.3 cdefgh
Pristine	89.5 $\pm$ 5.8 bcde	105.3 $\pm$ 3.5 ij	255.8 $\pm$ 15.2 bcd
Red Bandit	89.9 $\pm$ 5.0 bcde	140.0 $\pm$ 8.3 cdefg	218.5 $\pm$ 6.2 efgh
Sarah	91.9 $\pm$ 2.9 bcde	129.2 $\pm$ 12.3 fghi	201.1 $\pm$ 14.2 hi
Snowdrift	85.7 $\pm$ 3.5 def	98.7 $\pm$ 4.9 j	221.2 $\pm$ 17.8 defgh
Starburst	81.7 $\pm$ 3.5 efg	103.7 $\pm$ 8.5 j	216.6 $\pm$ 22.0 fgh
Tinkerbelle	71.2 $\pm$ 2.4 ghi	134.1 $\pm$ 5.9 efgh	169.9 $\pm$ 10.7 ij

^zGrowth index was calculated as height + width 1 + width 2. Width 1 and width 2 measured perpendicular to each other with width 1 at the widest point; 1 cm = 0.3937 inch.

^yMeasurements were taken before plants were transplanted to 3-gal (11.4 L) containers in 2015.

^xData followed by different letters within the column mean they were significantly different at $P < 0.05$ according to Fisher's least significant difference.

growth indices in 2015 (≥ 145 cm) and 2017 (≥ 230 cm), despite having smaller size in 2014 compared with 'Bullseye', 'Forever Red', 'Freckles', 'Heart of Fire', 'Olympic Fire', 'Ostbo Red', and 'Pink Charm'. On the basis of these results, nine mountain laurel cultivars including Bullseye,

Carol, Forever Red, Freckles, Heart of Fire, Olympic Fire, Ostbo Red, Peppermint, and Pink Charm would be good candidates for production in 1-gal containers and could be sold after a single year in production. Transplanting these cultivars in the second year from 1- to 3-gal containers and

selling them as 3-gal containers is also an option for growers. Although this increases input(s), labor, facility, and shipping resources, the fast growth rate of these cultivars and higher prices of 3-gal containers may compensate for additional inputs.

In contrast, 'Firecracker', 'Kaleidoscope', 'Minuet', 'Nathan Hale', and 'Tinkerbell' yielded less than 80 cm of total growth in 2014 (Table 3). 'Firecracker' and 'Kaleidoscope' were considered to be dense/compact growers and accordingly had smaller growth indices of <115 and 180 cm in 2015 and 2017, respectively. Interestingly, two cultivars frequently marketed as dwarf, Minuet and Tinkerbell, had greater growth indices in 2015 when compared with Firecracker and Kaleidoscope. Three cultivars marketed as dwarf spreading cultivars including Elf, Little Linda, and Starburst and four nondwarf cultivars including Pristine, Red Bandit, Sarah, and Snowdrift displayed moderate growth throughout the 4-year container evaluation. These slow and moderate growers could also reach a salable size in a 1-gal container in 1 year. An additional 2 years would be required to reach a salable size in a 3-gal container as defined by a growth index of 150 cm that is common among plants at the time of sale.

'Elf', 'Freckles', and 'Goodrich' were trialed in container production at Griffin, GA, and Puyallup, WA. by Hummel et al. (1990). Rooted liners of 'Elf' and 'Freckles' yielded more than 25 cm of growth index (height + width/2) in 6 months of production at both locations, with 'Freckles' having overall greater size than 'Elf'. This corroborates our results, in that 'Freckles' was a fast grower while 'Elf' had moderate size throughout the evaluation period. Because limited studies have been conducted to quantify the growth of container-grown mountain laurel, container trial results from this study provide novel detailed growth information for the 21 cultivars tested.

MORPHOLOGY. The 21 mountain laurel cultivars trialed in this study were subjected to morphological analysis of 11 phenotypic traits (Table 1). PCA indicated that the first four components accounted for 30.07%, 21.65%, 13.08%, and 11.08% of the morphological variance respectively, their cumulative variance

being 75.88% (Table 4). On the basis of eigenvector values for traits along the first two components, the major traits responsible for morphological diversity were flower size, bud color, and habit along the first component (PC1). Leaf color, leaf size, and leaf blade fell along the second component (PC2). The first two components were used to visualize a scatter plot whereby cultivars were divided into five groups (Fig. 2). The first

group (group 1) consisted of 10 cultivars including Bullseye, Carol, Firecracker, Forever Red, Heart of Fire, Nathan Hale, Olympic Fire, Ostbo Red, Pink Charm, and Sarah that had higher PC1 values. These cultivars had typical (nondwarf) habit and deep pink to red flower buds. Six cultivars including Freckles, Kaleidoscope, Little Linda, Peppermint, Red Bandit, and Tinkerbell having PC1 value near 0, were classified into two

Table 4. Eigenvectors and eigenvalues generated by principal component analysis (PCA) applied on 11 morphological characteristics of 21 mountain laurel cultivars.

Variable	Eigenvectors			
	PC1	PC2	PC3	PC4
Habit	0.626	-0.650	0.044	0.032
Stem and petiole color	0.599	0.324	0.517	-0.055
Leaf size	0.573	-0.617	0.026	0.416
Leaf blade	0.262	-0.604	0.251	-0.470
Leaf surface	0.580	0.148	-0.654	0.156
Leaf color	0.288	0.783	0.284	0.284
Flower size	0.823	-0.264	-0.007	0.133
Bud color	0.807	0.431	-0.034	0.056
Corolla color	0.485	0.286	0.374	-0.541
Pigment pattern	-0.277	-0.124	0.585	0.633
Blooming time	0.315	0.348	-0.337	0.028
Eigenvalues				
Eigenvalue	3.308	2.381	1.439	1.219
Percent of total variance explained	30.070	21.650	13.081	11.078
Cumulative percent of total variance explained	30.070	51.720	64.800	75.879

Fig. 2. Scatter plot of 21 mountain laurel cultivars obtained performing principal component analysis (PCA) on 11 morphological characteristics related to habit, stem, leaf, and flower. PC1 and PC2 explain 30.07% and 21.65% of morphological variation, respectively, with cumulative variance being 51.72%. Twenty-one cultivars were classified into five phenotypic groups based on PC1 and PC2 values.

groups based on their different PC2 values. The first group (group 2) contained two dwarf cultivars, Little Linda and Tinkerbell, that had V-shaped foliage and pink flowers, whereas the second group (group 3) comprised four nondwarf cultivars including Freckles, Kaleidoscope, Peppermint, and Red Bandit that had pigmented (in spot or band pattern) pink flowers. Cultivars Pristine and Snowdrift comprised group 4, separated from other cultivars by low PC2 values. These two cultivars displayed medium green stem and foliage and pure white inflorescence that were very distinctive. Three dwarf cultivars, Elf, Minuet, and Starburst, comprised group 5, based on low PC1 values. These three cultivars had more dense habit and lighter pink buds compared with Little Linda and Tinkerbell. The results confirmed visual observations, in that mountain laurel cultivars have a wide range of morphological combinations. Yet, PCA also indicated sharing of traits among five distinct groups. This classification information should provide plant breeders with useful information that affords insight into breeding for optimal growth index combined with favorable phenotypic characteristics. Additionally, growers in the southeastern United States could use this information to select cultivars having optimal growth indices from each of five groups. This would afford growers the ability to select fast-growing cultivars while maximizing phenotypic diversity in a minimum number of cultivars.

LEAF SPOT INCIDENCE. The majority of cultivars selected for this study were reported as leaf spot tolerant in the northeastern United States. No leaf spot was observed on cultivars Ostbo Red, Pristine, and Tinkerbell, whereas all other cultivars in this study had observed leaf spot incidence. Similarly, Jaynes (1988) observed that ‘Ostbo Red’ and ‘Tinkerbell’ showed higher tolerance to leaf spot compared with other cultivars. ‘Pristine’ was selected from a seed-lot collected in a wild population growing within 30 km of Woodlander Nursery [Aiken, SC, USDA Zone 8a (USDA, 2012)]. This is one of few cultivars on the market that was introduced from a selection program in the southeastern United States. As a result of continual disease

pressure observed in the southeastern United States and the fact that ‘Pristine’ was selected from a native population in the region that evolved in these conditions, ‘Pristine’ is more likely to have higher level of tolerance to leaf spot. Similar results were obtained in leaf spot tolerance studies in rabbiteye blueberry (*Vaccinium ashei*) selections that were derived from genotypes developed and/or selected from wild types in the southeastern United States. In the case of rabbiteye blueberry, leaf spot tolerance was tied to greater adaptability of genotypes derived from southeastern U.S. germplasm that were subjected to hot and humid conditions of the southeastern United States, compared with northern highbush blueberry [*Vaccinium corymbosum* (Scherer, 2008)].

FIELD TRIAL. Plants were rated using a 1 to 5 scale at the conclusion of the 2014 and 2015 growing seasons. Performance rating of 21 cultivars ranged from 2.0 to 4.8 in 2014 and from 2.0 to 5.0 in 2015, with differences observed among cultivars in 2014 (Table 2; Fig. 3). Four cultivars (rating ≥ 4) performed well during the 2014 growing season: Elf, Ostbo Red, Red Bandit, and Tinkerbell. Seven of 21 cultivars received similar ratings (rating ≥ 4) in 2015, including Carol, Little Linda, Minuet, Peppermint, Pristine, Sarah, and Tinkerbell. The majority of cultivars had superior or equivalent field performance ratings in 2015 compared with 2014, whereas Red Bandit, Starburst, and Tinkerbell had lower performance ratings in 2015 (Fig. 3). Improved field performance of most

Fig. 3. Field performance rating of 21 mountain laurel cultivars at the University of Georgia Durham Horticulture Farm in Watkinsville, GA, after the 2014 growing season (black bar) and 2015 growing season (gray bar). Plants were evaluated using a scale of 1 (dead) to 5 (excellent) and the rating was based on overall plant size and vigor, leaf color, incidence of leaf spot, and abiotic leaf and shoot damage. Data are presented as mean $\pm$ SE ($n = 4$) by the descending order of ranking in 2015. Different letters indicate that performance ratings of cultivars in 2014 are significantly different at $P < 0.05$ according to Fisher's least significant difference.

cultivars in year 2 indicated mountain laurel could have enhanced performance in landscapes after establishment (observed in year 2) and adapt to local southeastern U.S. conditions (high heat and humidity). On the basis of the rating results from 2014 and 2015, the 10 highest rated cultivars (Carol, Elf, Firecracker, Little Linda, Minuet, Ostbo Red, Peppermint, Pristine, Sarah, and Tinkerbell) were subsequently evaluated for field performance at the UGA Riverbend Research Center in 2016.

There was no significant difference in performance rating among the 10 cultivars field-trialed in 2016 (Table 2). Performance ratings in 2016 ranged from 1.0 to 3.3, lower than the initial field trial in 2014–15 (Table 5). ‘Elf’ received consistently high ratings after the initial field trial in 2014 (4.0) and 2015 (3.8), yet its performance rating dropped to 1.8 in 2016 (Table 5; Fig. 3). This reduction in performance rating could be due to transplant date. The initial field trial, conducted in 2014–15, was planted in Fall 2013 (1 Oct. 2013). Hanson et al. (2004) reported the main difficulty in establishing container-grown mountain laurel plants in landscapes was the lack of root extension into backfill-soil after transplanting in spring. Fall planting, as observed in the first field study conducted in 2014–15, was proceeded

by fall and winter conditions typified by extended cool temperatures and higher soil moisture when compared with spring plantings. This resulted in lower transpiration in the Fall 2013–planted field trials and likely led to enhanced establishment that improved later performance when compared with plants established in Spring 2016. Although spring–summer establishment conditions following transplant in 2016 were overall unfavorable (higher physiological stress) compared with the Fall 2013 establishment period; ‘Ostbo Red’, ‘Pristine’, and ‘Tinkerbell’ continued to exhibit higher performance ratings. ‘Ostbo Red’ and ‘Tinkerbell’ had more net growth (>50 cm) than other cultivars, whereas ‘Pristine’ exhibited slightly less net growth (35 cm) due to its comparably dense habit (Table 5).

Maximum quantum yield of photosystem II (F_v/F_m) is a measure of plant stress, particularly heat stress (Baker and Rosenquist, 2004). F_v/F_m for most plants grown in minimal environmental stress conditions is ≈ 0.79 – 0.83 , while values lower than this range suggest that plants have been exposed to stress and photosystem II reaction centers are damaged (Kalaji et al., 2012; Maxwell and Johnson, 2000). The F_v/F_m measured on mountain laurel plants before 2016 transplant ranged from

0.78 to 0.84, whereas all cultivars showed decreased F_v/F_m (0.00 to 0.80) at the conclusion of field trials. Decrease in F_v/F_m was therefore used to compare the ability of mountain laurel cultivars to adapt to southeastern U.S. environmental conditions. In this scenario, a lower percentage decrease in F_v/F_m indicated less damage of photosystem II and therefore enhanced stress tolerance. Negative correlation between percentage decrease in F_v/F_m and performance rating was observed among all cultivars. ‘Ostbo Red’, ‘Pristine’, and ‘Tinkerbell’ had less decrease in F_v/F_m (<51%), whereas other cultivars had greater decrease in F_v/F_m (>70%) (Table 5). When combined with performance ratings, F_v/F_m appeared to be a parameter that could reflect stress tolerance of mountain laurel cultivars.

Conclusion

Twenty-one mountain laurel cultivars displayed various responses to container and field trials when evaluated in the southeastern United States (USDA Zone 8a). Although the 21 cultivars displayed differing growth indices in container production, all cultivars could yield sufficient growth the first year after being transplanted into 1-gal containers and consistently perform well thereafter in a container production environment. This indicated that growing mountain laurel for 1 year as 1-gal container plant should be feasible for southeastern U.S. producers. Fast-growing cultivars including Bullseye, Carol, Forever Red, Freckles, Heart of Fire, Olympic Fire, Ostbo Red, Peppermint, and Pink Charm could be shifted up to and finished in 3-gal containers. Additionally, mountain laurel cultivars had a variety of morphological characteristics and fell into five phenotypic (PCA) groups based on shared morphological traits when grown in a container production environment, principally on habit, foliage, and inflorescence traits. Results of this study should benefit plant breeders and commercial producers by providing regional cultivar information for the southeastern United States (and other USDA Zone 8–9 environments). ‘Ostbo Red’, ‘Pristine’, and ‘Tinkerbell’ would be recommended to the southeastern U.S. producers to have both phenotypic variability in the cultivars produced

Table 5. Field performance rating, net growth, and percentage of decrease in maximum quantum yield of photosystem II (F_v/F_m) of 10 mountain laurel cultivars at the University of Georgia Riverbend Research Center at Athens, GA, in 2016 (n = 4).

Cultivar	Rating (1–5 scale) ^a	Net growth (cm) ^b (mean ± SE)	Decrease in F_v/F_m (%) ^c
Ostbo Red	2.5 ± 0.7	58.7 ± 11.7 a ^w	43.8 ± 33.0
Peppermint	1.5 ± 0.5	55.6 ± 10.6 ab	73.8 ± 26.2
Tinkerbell	3.3 ± 1.0	54.8 ± 13.9 ab	49.8 ± 29.0
Little Linda	1.8 ± 0.8	49.0 ± 4.6 abc	75.3 ± 24.7
Firecracker	1.0 ± 0.0	43.6 ± 1.5 abc	100.0 ± 0.0
Minuet	1.5 ± 0.5	40.5 ± 17.0 abc	75.9 ± 24.1
Sarah	1.0 ± 0.0	39.4 ± 7.5 abc	100.0 ± 0.0
Pristine	2.8 ± 1.0	35.3 ± 4.1 abc	50.9 ± 29.0
Elf	1.8 ± 0.8	32.7 ± 5.9 bc	72.8 ± 27.2
Carol	2.0 ± 1.0	28.9 ± 16.0 c	74.4 ± 25.6

^aField performance rating was evaluated using a scale of 1 (dead) to 5 (excellent) and the rating was based on overall plant size and vigor, leaf color, incidence of leaf spot, and leaf and shoot abiotic damage.

^bGrowth index was calculated as height + width 1 + width 2. Width 1 and width 2 measured perpendicular to each other with width 1 at the widest point. Net growth was calculated as final growth index–initial growth index; 1 cm = 0.3937 inch.

^cInitial and final F_v/F_m were measured on plants before being planted to the field and after growing season, respectively. The percentage of decrease in F_v/F_m was then calculated as [(initial F_v/F_m – final F_v/F_m)/initial F_v/F_m × 100%].

^wData are sorted by descending numerical values of net growth. Data followed by different letters within the column indicate differences in mean values at $P < 0.05$ according to Fisher’s least significant difference.

and leaf spot tolerance. Although most cultivars in this study had difficulty establishing in southeastern U.S. landscapes, fall planting could facilitate improved establishment. Three cultivars, Ostbo Red, Pristine, and Tinkerbelle, consistently excelled in field trials, indicating that they are more adapted to landscape environmental conditions observed in the southeastern United States.

Literature cited

- Baker, N.R. and E. Rosenquist. 2004. Applications of chlorophyll fluorescence can improve crop production strategies: An examination of future possibilities. *J. Expt. Bot.* 55:1607–1621.
- Dirr, M.A. 2009. *Manual of woody landscape plants*. 6th ed. Stipes Publishing, Champaign, IL.
- Givnish, T.J. 1984. Leaf and canopy adaptations in tropical forests, p. 51–84. In: E.H. Medina, A. Mooney, and C. Vasquez-Yanes (eds.). *Physiological ecology of plants in the wet tropics*. D. W. Junk Publ., The Hague, The Netherlands.
- Hanson, A.M., J.R. Harris, and R. Wright. 2004. Effects of transplant season and container size on landscape establishment of *Kalmia latifolia* L. *J. Environ. Hort.* 22:133–138.
- Hummel, R.L., C.R. Johnson, and O.M. Lindstrom. 1990. Root and shoot growth response of three container-grown *Kalmia latifolia* L. cultivars at two locations to growing medium and nitrogen form. *J. Environ. Hort.* 8:10–13.
- Jaynes, R.A. 1982. New mountain laurel selections and their propagation. *Intl. Plant Prop. Soc. Proc.* 32:431–434.
- Jaynes, R.A. 1988. *Kalmia: The laurel book*. Timber Press, Portland, OR.
- Kalaji, H.M., R. Carpentier, S.I. Allakhverdiev, and K. Bosa. 2012. Fluorescence parameters as early indicators of light stress in barley. *J. Photochem. Photobiol. B.* 112:1–6.
- Kurmes, E.A. 1967. The distribution of *Kalmia latifolia* L. *Amer. Midl. Nat.* 77:525–526.
- Maxwell, K. and G.N. Johnson. 2000. Chlorophyll fluorescence—a practical guide. *J. Expt. Bot.* 51:659–668.
- Scherm, H. 2008. Disease management in organic rabbiteye blueberries. *Intl. J. Fruit Sci.* 8:69–80.
- Schlichting, C.D. 1986. The evolution of phenotypic plasticity in plants. *Annu. Rev. Ecol. Syst.* 17:667–693.
- European Kalmia Society. 2018. Laurel cultivars—the international *Kalmia* register and checklist. 2 Oct. 2018. <<http://www.kalmia-society.org/cultivars.php?&lang=gb>>.
- U.S. Department of Agriculture (USDA). 2012. USDA plant hardiness zone map. 1 Aug. 2018. <<http://planthardiness.ars.usda.gov/PHZMWeb>>.