Shade Influences Plant Growth, Leaf Color, and Chlorophyll Content of *Kalmia latifolia* L. Cultivars

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Abstract. The effect of shading during nursery production on the growth, foliage color, and foliar chlorophyll content of container-grown *Kalmia latifolia* cultivars was investigated. Five cultivars were grown under 40% shade, 60% shade, or full sunlight for a 2-year production cycle. During the first year of production, there were no significant differences in measured growth characteristics for most cultivars in response to light treatment. Shade improved foliar color by decreasing lightness (L^*), decreasing chroma, and changing hue angle from a yellow-green to a darker green. Foliar chlorophyll concentration increased under shade. In the second year of the production cycle, the response of foliar color and chlorophyll concentration to shade was similar to that observed in year 1. Plant size, number of branches, leaf area, leaf dry mass, and stem dry mass decreased linearly with increasing shade in year 2. Although shading improves foliar color, it probably should not be employed for container production of *Kalmia latifolia* in cool, northern production areas due to reduced plant growth during year 2. Shade may be useful in the first year of production to enhance foliar color without reducing shoot growth.

Kalmia latifolia (mountain laurel) is a member of the *Ericaceae* native to the eastern United States. It is a broadleaved evergreen shrub noted for its showy flowers and recently became popular as a landscape plant (Jaynes, 1988b). Breeding and selection efforts over the last 35 years have produced new mountain laurel cultivars with various flower colors, improved growth habit, and greater landscape adaptability (Jaynes, 1988a).

The market demand for mountain laurel for landscape use is high. Micropropagation of mountain laurel has made propagules of improved cultivars readily available to growers (Lloyd and McCown, 1980). However, a lack of knowledge concerning cultural requirements for container-grown mountain laurel has limited commercial production. Bir and Bilderback (1989) indicate that few nurseries are consistently producing high-quality container-grown mountain laurel and that many are looking for advice on optimum production practices.

In general, mountain laurel is considered to have the same cultural requirements as other ericaceous plants. In the southeastern United States, container-grown mountain laurel requires shade from high pine trees or 50% shade from lath or fabric for good production (Bir and Bilderback, 1989). The shade is needed to reduce foliar and particularly root-zone temperatures of plants with heat-sensitive roots

(Ingram, 1981; Whitcomb, 1984). Phillips et al. (1991), in comparing 55% white shade cloth to 20% black shade cloth in a region requiring shade, found that differences in light intensity and pot temperature resulting from differing types of shade cloth did not play a significant role in affecting plant growth. Bir and Bilderback (1989), suggested that in the northeastern United States, or other regions with cool growing seasons, high-quality mountain laurel can be grown in full sun. Hummel et al. (1990) compared plants grown under shade in Georgia to plants grown in full sun in Washington and demonstrated that high-quality plants could be produced in both locations. However, some northeastern growers have obtained suboptimal growth performance of containerized mountain laurel in full sun, especially when plants are small or repotting is delayed to summer (Brand, 1992); he suggested that root-zone heating, resulting from insufficient canopy shading of the potting medium, may be the cause of poor root growth.

The purpose of this study was to determine the effects of shading on plant growth, leaf color, and leaf chlorophyll content of containerized mountain laurel in a cool region of the United States, and on performance of a wide range of cultivars over an entire 2-year cropping cycle.

Materials and Methods

Plant material. Five currently produced mountain laurel cultivars were selected, representing a range of popular types. 'Bay State' was selected because it is a red bud/pink flower type that was developed separately from 'Carol', the other red-budded cultivar used in the study. 'Carol' is a compact plant and

highly rated by growers and landscapers. The *myrtifolia*-type 'Elf' was included because it is representative of a group of dwarf forms. 'Heart's Desire' was selected as a tall, vigorous plant and also because it has a banded corolla (f. *fusca*). The pure white-flowering 'Snowdrift' represented an unpigmented flower type. All plants had been micropropagated at the Univ. of Connecticut, using typical commercial procedures.

Plant culture. Uniform liners, grown in 0.5-L (10.2-cm) square pots (Kord Products, Ontario, Canada), were transplanted into 3-L containers (Classic 300S, Nursery Supplies, Fairless Hills, Pa.) on 1 May 1991. Plants were ≈ 12 cm tall and 12 cm wide at the time of transplanting. The potting medium was 3 pine bark : 2 peat moss : 1 sand (by volume) amended with dolomitic limestone at 3.6 kg-m⁻³. Containers were topdressed, following transplanting, with Sierrablend 17N-2.6P-8.3K 8 to 9 month formulation (The Scotts Co., Marietta, Ga.) at 10 g per plant. Plants were overwintered in a white polyethylene-covered hoop house from 6 Nov. 1991 until 22 Apr. 1992. Irrigation was provided during the growing season by trickle emitters on an as-needed basis for both years of the study. During the dormant season, irrigation was by hand as needed.

Plants were pruned 1 May 1992 according to accepted commercial practices, by removing most of the last growth flush of the previous season and further shaping the plants as needed. Following pruning, plants were transplanted into 7-L containers (Classic 600; Nursery Supplies), using the potting medium and fertilizer described previously. The controlled-release fertilizer was topdressed at 28 g per plant.

Shade treatments. Shade was provided by covering wooden support structures (2.2 m high, 6.1 m long, and 3.0 m wide) with black woven polypropylene material to provide 40% or 60% of maximum irradiation. Shading structures were oriented with the longitudinal axis running north-south. Shading covered the structures except for the bottom 15 cm, to minimize air temperature and movement differences. No wooden frames were provided for the full sun treatment. Plants were placed in shade from 1 May 1991 to 6 Nov. 1991 and again from 1 May 1992 to 15 Oct. 1992.

Growth quantification. For 1991, the end of the first growing season, growth measurements were taken on 15 to 17 Oct. Plant height, two plant widths (at right angles to each other), and number of branches were recorded for every plant. Plant size was estimated as a product of the plant height and two plant widths. Branches were defined as shoots comprised of two or more growth flushes. Measurements were also taken 2 and 3 May 1991, at the start of the growing season, to be used in covariance analysis. For 1992, end of the second growing season growth measurements were taken on 14 to 16 Oct., as described above. In addition to height and width, stem fresh and dry mass, leaf fresh and dry mass, number of leaves, and total leaf area were determined per plant for half of the plants. Leaf area was quantified using a model LI3100

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leaf area meter (LI-COR, Lincoln, Neb.). Plant measurements used for covariance analysis of 1992 data were those from the end of the first growing season (prior to pruning the next spring). Flower bud set was evaluated during the second year of the study, but was too low and variable to be useful in determining shade effect on flower bud set.

Color measurements. CIELAB coordinates for the abaxial leaf surface were measured with a Minolta CR-200b colorimeter (Minolta, Ramsey, N.J.) on 16 Sept. in 1991 and 1992. Three recently matured leaves per plant, from the upper third of the canopy, were measured on half of the plants of each cultivar by shade treatment combination. Leaf L^* a^* b^* values (Hunter, 1975) were measured at the midpoint between the distal and basal ends of the leaf. Leaf midribs were excluded from the sampling area except for 'Elf', where the lamina were too narrow to exclude the midrib. The colorimeter was calibrated at illuminant C with a white standard. Because of the slightly translucent nature of mountain laurel leaf tissue, a standard white background was placed behind each leaf when a CIELAB measurement was taken (Little, 1964). In addition to the CIELAB coordinated value (L^*), the coordinates of hue angle ($\tan^{-1}b^*/a^*$) and chroma ($a^{*2}+b^{*2}$) were calculated from a^* and b^* .

Chlorophyll extraction and quantification. Leaf disks for chlorophyll extraction were collected from the same leaves that color measurements were taken and on the same days. A 9-mm diameter cork borer was used to obtain leaf disks from three recently matured leaves per plant. Half of the plants in each cultivar by shade treatment combination were sampled. Each leaf disk was extracted in 3 mL of *N,N*-dimethylformamide for 24 h in darkness (Moran and Porath, 1980). Absorbance of leaf extracts was measured using a Spectronic 1201 spectrophotometer (Milton-Roy Co., Rochester, N.Y.). Chlorophyll concentration was determined from the equation of Inskeep and Bloom (1985), where chlorophyll ($\text{mg}\cdot\text{L}^{-1}$) = $17.90_{A_{647}} + 8.08_{A_{664.5}}$.

Experiment design and analysis. The design was a split-plot with shade as the fixed main plot. Within each main plot, there was a randomized complete-block arrangement with four blocks, each comprised of five plants of each cultivar. Data were subjected to analysis of variance or covariance by general linear model (GLM) procedures (SAS Institute, 1990). Plant size was used as the covariate for analysis of plant size, number of leaves per plant, leaf area per plant, leaf dry mass, and stem dry mass per plant. Branch count per plant was used as the covariate for analysis of branch count per plant. The effect of shade was determined for each cultivar using single-degree-of-freedom orthogonal polynomial contrasts. Data for 1991 and 1992 were analyzed separately.

Results

Plant growth. Shading had no effect on plant size by the conclusion of the first growing season, regardless of the cultivars tested.

Most cultivars also produced similar numbers of branches in response to shading at the conclusion of the first year (Table 1). Only 'Elf' produced more branches in response to shade.

At the end of the second growing season, plant growth responses to shading were highly significant. For all cultivars, plant size and number of branches decreased linearly with increasing shade (Table 1). Number of leaves, leaf area, leaf dry mass, and stem dry mass decreased linearly for all cultivars as shade increased (Table 2). Leaf and stem fresh mass (not presented) responded similarly to leaf and stem dry mass in response to shade.

Foliage color. During the first year of production, shading significantly influenced the leaf color of all mountain laurel cultivars studied (Table 3). In this study, leaf hue angles ranged from 115° to 135° . Hue angle increased linearly with added shading for all cultivars. The leaves were a yellow-green hue under full sunlight and a greener (less yellow) hue under shade. For all cultivars, L^* (lightness) of the leaf color decreased linearly as shade was increased (Table 3). Chroma values declined linearly in response to increasing shading for all cultivars, indicating that shading made foliage color duller (Table 3). Higher absolute values for chroma indicate more vivid colors, while values closer to zero are duller. The decline in L^* and chroma are consistent with a change in hue angle from yellow-green to green, since yellow pigments have higher chroma and L^* than green ones. When considered together, the findings for L^* , hue angle, and chroma indicate that mountain laurel foliage color generally becomes darker green in response to shading during the first year of production.

All cultivars showed significant increases in foliar chlorophyll content in response to shade (Table 3). CIELAB and chlorophyll concentration data collected at the conclusion

of year 2 of the study (not presented) were similar to those for year 1.

Discussion

Although the genetic background was diverse for the mountain laurel cultivars used, all cultivars appeared to respond similarly to shading. During year 2, growth was generally reduced by shading. For *Photinia x fraseri* Dress, shade was also found to reduce total leaf area, number of leaves per plant and dry mass of stems and leaves (Norcini et al., 1991). For another woody species, *Cornus stolonifera* Michx., plant growth was optimized with 25% shading, but reduced with more shading (Sheppard and Pellett, 1976). When grown in the warmer regions of the United States, some woody plants, and particularly many evergreens, benefit from shading. Working in Mississippi, Newman and Follett (1988) found that shading with 53% polypropylene cloth increased *Euonymus japonica* Hand.-Mazz. 'Aureo-marginata' plant dry mass, leaf area and root dry mass. Shade was also shown to increase leaf and stem dry mass and leaf area in *Rhododendron* x 'Pink Ruffles', which, like mountain laurel, is a member of the *Ericaceae* (Andersen et al., 1991).

During both years of the study, shading improved leaf color, producing plants with darker green leaves than those produced under full sunlight. This leaf color gave the shaded plants the appearance of being healthier than plants grown under full sunlight. The improved leaf color was related to increased foliar chlorophyll content. Increases in foliar chlorophyll concentration in response to shading have been reported for *Rhododendron* (Andersen et al., 1991) and *Euonymus* (Newman and Follett, 1988).

Shading clearly reduced mountain laurel shoot growth during year 2, but not during year 1 of the study. There may be a beneficial

Table 1. Effect of shade on adjusted treatment means for calculated plant size and number of branches for container-grown *Kalmia latifolia* cultivars for 2 years of a production cycle.

		Plant characteristic				
		Cultivar				
	Shade (%)	Baystate	Carol	Elf	Heart's Desire	Snowdrift
Year 1						
		Number of branches				
	0	8.6	10.1	6.4	7.8	5.0
	40	9.8	10.6	9.4	9.0	4.5
	60	8.3	10.7	8.3	7.6	5.9
Significance ^z		NS	NS	**	NS	NS
Year 2						
		Plant size (cm ³ , 1000s) ^y				
	0	48.8	54.2	39.6	87.6	41.0
	40	40.1	35.9	26.4	65.2	26.0
	60	32.6	35.1	23.6	58.7	23.4
Significance		**	**	**	**	**
		Number of branches				
	0	15.4	26.0	30.6	28.3	14.9
	40	10.8	18.7	24.5	17.3	11.3
	60	11.9	15.5	25.3	15.1	12.4
Significance		**	**	**	**	*

^aSignificance of the linear model using analysis of covariance at $P \leq 0.05$ (*) or 0.01 (**). Plant size was used as the covariate for plant size and number of branches was used as the covariate for itself.

^bPlant size is the product of two plant widths taken at right angles to each other and plant height.

effect of shading in year 1, which compensates for potential growth reduction by shade as observed in year 2. A moderate level of shading may reduce heating of the potting medium surface for young plants where the plant canopy provides insufficient shading of the medium and pot surfaces. A cooler potting medium may benefit root functioning and growth, such that it compensates for reduced photosynthesis under shade. In larger, second-year plants, the roots and the potting medium are shaded by a full foliage canopy, so plants in full sun are less likely to experience heat-related root-zone problems and, therefore, only benefit from higher light levels.

After visiting several commercial growers, Bir and Bilderback (1989) suggested that shade was not needed to grow high-quality mountain laurel in the northeastern United States. The results of this study generally confirm these empirical observations. However, shading mountain laurel during production in cooler climates may be useful in some instances. Since growth was not inhibited by shade during year 1 of production, growers marketing 1-year-old plants may increase plant marketability by improving foliar coloration by shading during production. Shading during the first year of production may also maintain a cooler root zone for younger plants, possibly enhancing root development and growth under full sunlight during following growing seasons. Growers utilizing shading should use 40%, rather than 60% shade. Although not evaluated, shading of 20% to 30% might provide enhanced foliage color without reducing plant growth.

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Table 2. Effect of shade during the second year of production on number of leaves per plant, leaf dry weight per plant, leaf area per plant, and stem dry weight per plant for container-grown *Kalmia latifolia* cultivars.

Shade (%)	Plant characteristics				
	Cultivar				
	Baystate	Carol	Elf	Heart's Desire	Snowdrift
<i>Number of leaves</i>					
0	271	433	1076	488	236
40	199	346	663	322	189
60	140	280	497	236	136
Significance ²	**	**	**	**	*
<i>Leaf area (cm²)</i>					
0	2228	3103	2499	3248	1598
40	2166	2913	1680	2451	1513
60	1571	2337	1188	1944	1205
Significance	*	**	**	**	*
<i>Leaf dry mass (g)</i>					
0	55	82	53	77	37
40	39	57	29	43	27
60	26	43	20	32	22
Significance	**	**	**	**	*
<i>Stem dry mass (g)</i>					
0	18.0	29.4	37.2	44.7	16.1
40	12.7	20.7	18.7	24.5	14.4
60	8.5	16.4	14.8	20.2	9.6
Significance	**	**	**	**	*

²Significance of the linear model using analysis of covariance at $P \leq 0.05$ (*) or 0.01 (**). Plant size was used as the covariate.

Table 3. Foliar CIELAB coordinates and chlorophyll concentrations for container-grown *Kalmia latifolia* cultivars provided shade or full sunlight during the first year of production.

Shade (%)	Plant characteristics				
	Cultivar				
	Baystate	Carol	Elf	Heart's Desire	Snowdrift
<i>Hue angle</i>					
0	117.1	116.2	119.3	116.0	122.4
40	131.9	129.7	129.0	124.8	132.2
60	133.5	133.3	130.3	131.6	132.7
Significance ²	**	**	**	**	**
<i>L*</i> ³					
0	37.4	43.1	36.6	42.4	40.9
40	33.8	35.4	33.7	33.7	34.0
60	32.7	33.6	33.0	32.6	34.0
Significance	**	**	**	**	**
<i>Chroma</i>					
0	20.0	28.3	19.5	34.0	22.0
40	14.8	15.8	14.0	20.4	12.3
60	10.9	11.6	12.2	14.3	11.8
Significance	**	**	**	**	**
<i>Chlorophyll (ug cm⁻²)</i>					
0	22.4	19.7	20.4	14.2	19.1
40	33.2	28.8	33.3	28.5	31.9
60	38.6	39.4	38.6	30.9	35.0
Significance	**	**	**	**	**

²Significance of the linear model using analysis of variance at $P \leq 0.05$ (*) or 0.01 (**).

³L* is the value of a color and quantifies the lightness or darkness of a color. Larger values represent whiter colors and smaller values darker colors.

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