Production schedules for these species in the spring and summer months are very similar. Cuttings are stuck in a pinebark-based substrate using 72 cell trays and roots initiate within 2 to 3 weeks. Rooted cuttings are removed from the mist on week 3 or 4 and the plants remain in these flats through weeks 5 to 6. Seacoast marshelder and false rosemary may be pruned in weeks 4 or 5 prior to transplant or within 1 week after transplant to initiate branching. Gulf bluestem and Atlantic St. Johnswort, in general, will not require pruning. Following transplant into 1-liter (4-inch) pots, plants require an additional 4- to 6-week production period to achieve a full rootball and a canopy of approximately 15 to 20 cm.

Benefits of Shade During Production of *Illicium*: Optimizing Growth and Nutrient Recovery©

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We conducted a study to elucidate the optimal light intensity for growth and nutrient recovery for two taxa of *Illicium*. Plants were grown under three light treatments, 45%, 70%, and 100% of full sun using standard nursery practices. Growth indices, final dry mass, and SPAD chlorophyll meter readings were taken at the conclusion of the experiment. Tissue analysis for N, P, and K were conducted to determine percent recovery of applied nutrients. Growth and SPAD readings for *I. floridanum* Ellis. 'Pebblebrook' decreased as light level increased from 45% to 100% of full sun. *Illicium parviflorum* Michx. ex. Vent. 'Forest Green' growth also decreased as light level increased, but SPAD readings were unaffected. For both taxa, optimum nutrient uptake of nitrogen, phosphorus, and potassium occurred in the 45% light treatment. To improve production efficiency of container-grown *Illicium* taxa we recommended growers produce *Illicium* taxa in light intensities of less than full sun.

INTRODUCTION

Light intensity during production of container-grown ornamentals not only affects growth rates for specific plants, but also overall plant quality. This is of particular importance for broad-leaf evergreens, where growth in high light intensities may lead to photobleached and chlorotic foliage (Andersen et al., 1991a; 1991b) from prolonged photoinhibition (Lambers et al., 1998). *Illicium*, or star-anise, is a popular genus of broad-leaf evergreens trees and shrubs native to parts of southeastern Asia and southeastern North America and Mexico (Smith, 1947). Currently, many nurseries in the southeastern U.S.A. grow *I. parviflorum* in full sun and *I. floridanum* in shade.

Olsen and Ruter (2001) compared photosynthetic rates of various *Illicium* taxa grown in 100% or 45% of full sun, with maximum rates of photosynthesis occurring in the 45% light treatment. *Illicium parviflorum* 'Forest Green' maintained similar rates of photosynthesis in 100% light as in the 45% light treatment; however, they predicted that maximum growth would occur for this taxon in 45% light where

respiration rates were lower (Olsen and Ruter, 2001). Griffin and Ranney (2001) conducted a similar study in the Piedmont of North Carolina (USDA hardiness Zone 7) and concluded that *I. parviflorum* 'Forest Green' was suitable for growth in high light conditions, as well as a number of other *Illicium* taxa. In both of the above studies, growth was not measured.

Predictions of adaptability for *Illicium* taxa based on single leaf measurements of photosynthesis may not always correlate well with overall plant growth and performance. During container-production growers must consider their total inputs during a cropping cycle, including water, nutrients, and labor when determining which light intensity is best for a particular crop. The optimal light intensity during production, therefore, should be that light intensity which maximizes growth and plant quality, while minimizing grower input. Therefore, a production study was conducted to evaluate growth, foliage quality, and nutrient recovery of container-grown *Illicium* taxa to various light intensities and to identify the light intensity that optimizes these parameters.

MATERIALS AND METHODS

Uniform liners of *I. floridanum* 'Pebblebrook' and *I. parviflorum* 'Forest Green' were potted into 2.8-liter (#1 gallon) black plastic containers containing a substrate of milled pine bark and sand (8 : 1, v:v) amended with dolomitic lime at 1.2 $kg \cdot m^{-3}$ (2 lb per yd^3). Osmocote Plus 15N-4P-9.9K 8-9 month Southern formula (Scotts Co., Marysville, Ohio) was applied as a top dressing at 1.2 kg N per m^3 (2 lb per yd^3). Plants were grown under three different light intensities: 45%, 70%, and 100% of full sun. Plants in 45% and 70% were grown in hoop houses covered with black woven polypropylene fabric of the desired light transmission. Plants in 100% light were grown in full sun on a nursery container pad. Plants were watered as needed.

The study began in May 2000 and ended November 2000. Final plant height, width 1, and width 2 (plant width perpendicular to width 1) were measured. Growth index (GI) (height 1 plus width 1 plus width 2/3) was calculated. A SPAD-502 chlorophyll meter (Minolta, Ramsey, N.J.) reading was taken on two leaves per plant, midway between the leaf margin and the mid-vein, and were averaged. Plants were harvested for dry weight determination. All plant parts were dried to a constant dry mass, and ground for tissue analysis. Tissue nitrogen (N) was analyzed using a copper catalyst Kjeldahl method. Phosphorus (P) and potassium (K) were analyzed with a microwave digestion method and absorbance spectrophotometry. Total N, P, and K accumulation per plant were determined by multiplying total nutrient content by the plants dry mass. Percent recovery of N, P, and K was determined by calculating the total nutrient load applied from the fertilizer, assuming negligible rates were supplied by the pine bark substrate. Each container received approximately 3.0 g N, 0.5 g P, and 1.7 g K. Total plant nutrient accumulation was divided by the total nutrient applied for each container and multiplied by 100 to give the percentage of nutrient recovery.

Each taxon was analyzed separately. There were three light intensities with eight single plant replicates per light treatment. Data for the entire experiment were subjected to analysis of variance. Although no control was designated for the experiment, treatment effects are presented as deviations from plants of *I. floridanum* 'Pebblebrook' or *I. parviflorum* 'Forest Green' grown in 45% light.

RESULTS AND DISCUSSION

Optimal growth occurred in 45% light for both *I. floridanum* 'Pebblebrook' and *I. parviflorum* 'Forest Green', as seen in the decreasing growth indices and dry mass measurements as light level increased (Table 1). The decreases in growth index and dry mass are indicative of decreased carbon accumulation for plants in high light, in part due to lower photosynthesis and increased respiration of *Illicium* plants in full sun (Olsen and Ruter, 2001). For *I. floridanum* 'Pebblebrook', decreased growth in full sun was accompanied by decreases in SPAD, or "leaf greenness" readings (Table 1). Plants of *I. floridanum* 'Pebblebrook' in 70% light were lighter green than plants in 45% light, with plants in 100% light being photobleached and chlorotic. Foliage color of *I. parviflorum* 'Forest Green' was unaffected by light treatment, however, plants in 100% light had vertically disposed leaves, so much so that the stems appeared clothed in leaves. Plants in 45% light had leaves held in more of a horizontal disposition, with plants in 70% light being intermediate (personal observation). The severe vertical deposition of leaves in 100% light of *I. parviflorum* 'Forest Green' detracted from the overall visual quality of the plant when compared to plants grown in light intensities less than full sun. Norcini et al. (1991) made similar observations and conclusions when *Cercis canadensis* L. (eastern redbud) was grown in full sun.

Optimal growth coincided with optimal nutrient uptake and recovery for both taxa in this study. Substantial decreases in N, P, and K recovery percentages were observed when plants of both taxa were grown in light intensities greater than 45% light (Table 2). It has been suggested that optimal nutrient uptake occurs during periods of active growth (Wright and Niemiera, 1987). The increased growth of both *Illicium* taxa in our study in 45% light may be the result of higher rates of photosynthesis (Olsen and Ruter, 2001) and increased availability of photosynthates to supply the competing sinks of growth and nutrient uptake (Wright and Niemiera, 1987). Increased nutrient recovery in 45% light would result in substantial decreases of nutrients loss through leaching. The leaching of nitrates and phosphates into the environment is of critical concern to production nurseries. By growing *Illicium* taxa in light intensities of less than full sun, growers can increase fertilizer efficiency and thus production efficiency, while minimizing losses to the environment.

Table 1. Percent changes in final growth index, dry mass, and SPAD meter readings for *Illicium floridanum* 'Pebblebrook' and *I. parviflorum* 'Forest Green' grown in 70% and 100% of full sun compared to plants grown in 45% of full sun.

Taxa	Light level	Growth index	Dry mass	SPAD meter
Illicium floridanum 'Pebblebrook'	70%	-22%	-27%	-45%
	100%	-58%	-60%	-68%
I. parviflorum 'Forest Green'	70%	-9%	+3%	-3%
	100%	-25%	-32%	+1%

Table 2. Percent changes in nutrient recovery rates for *Illicium floridanum* 'Pebblebrook' and *I. parviflorum* 'Forest Green' grown in 70% and 100% of full sun compared to plants grown in 45% of full sun.

Taxa	Light level	Nutrient recovery rates N	P	K
Illicium floridanum 'Pebblebrook'	70%	-20%	-79%	-15%
	100%	-56%	-86%	-61%
I. parviflorum 'Forest Green'	70%	-4%	-40%	-3%
	100%	-31%	-41%	-33%

Growth and quality of *I. floridanum* 'Pebblebrook' was not satisfactory in 100% light and reflects current nursery practices where clones of *I. floridanum* are produced under shade. However, many nurseries produce *I. parviflorum* in full sun, where we have demonstrated decreased growth and substantial decreases in nutrient uptake. It is suggested that growers also produce *I. parviflorum* 'Forest Green' in shade (approx. 45% of full sun) to increase growth, plant quality, and fertilizer efficiency, and thus production efficiency.

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