Response of Tropical Foliage Plants to Interior Low Light Conditions

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Keywords: *Anthurium*, *Dieffenbachia*, chlorophyll, *Ficus*, leaf specific area, light acclimatization, ornamental foliage plants, photosynthesis

Abstract

Tropical ornamental foliage plants have been widely used for interior plantscaping. This report summarizes our investigations on how some flowering and foliage plants adjust to interior low light conditions. *Ficus benjamina* 'Common', a green-leafed plant, adapted by increasing specific leaf area, internode length, and chlorophyll b content. Variegated-leafed *Dieffenbachia maculata* 'Camille' responded by decreasing leaf area, degree of variegation, and increasing chlorophyll content in the yellow-white leaf areas. Individual leaves of a flowering foliage plant, *Anthurium* × 'Red Hot', sustained net photosynthesis rates (*Pn*) under interior conditions and delayed leaf senescence. It produced new leaves and flowers. Additionally, changes in canopy configuration of both *Anthurium* and *Dieffenbachia* increased light interception. All plants investigated apparently maximized net photosynthesis rates under the low light environment. The species investigated maximized their net photosynthesis rates differently.

INTRODUCTION

Most foliage plants originated in the tropical and subtropical regions where they grow under tree canopies on shaded forest floors or live in trees as epiphytes (Henny and Chen, 2003). A distinct characteristic of many foliage plants is their ability to tolerate low light levels. Foliage plants have been predominately cultivated in shaded greenhouses. Finished plants can be directly placed in interiorscapes if produced under an appropriate light intensity or they must be acclimatized during the final production process (Conover and Poole, 1984; Chen et al., 2001). Acclimatization is a seriate process of adapting the plants to interior conditions. Low light is the most important factor influencing foliage plant performances under interior conditions.

Plants from at least 100 genera and 1000 species are grown as foliage plants. These plants have widely diverse forms, patterns of foliar variegation, and colors. Based on their appearances, foliage plants can be simply categorized into three groups: green-leaf, variegated-leaf, and flowering foliage plants. How these groups of the plants respond to interior low light conditions has not been previously documented. The objective of this report is to summarize our recent investigations on how representatives of these three plants categories responded to interior low light environments.

MATERIALS AND METHODS

Green Leaf Foliage Plant: *Ficus benjamina* 'Common'

1. Acclimatized *Ficus benjamina* Responses to Interior Low Light. Rooted cuttings of *Ficus benjamina* 'Common' were potted in 15-cm diameter containers filled with Vergo Mix A: 60% Canadian peat, 20% vermiculite, and 20% perlite by volume (Verlite Co. Tampa, FL) and grown in a shaded greenhouse under light levels of 50, 100, and 300 µmol/m^2/s. Net photosynthesis rates (*Pn*) of the plants were estimated by measuring 40 fully expanded mature leaves with a LCi portable photosynthesis system (ADC BioScientific Ltd., Hoddesdon, UK). Five plants from each light level were then placed in interior evaluation rooms with a light intensity of 16 µmol/m^2/s provided by fluorescent

lamps. All interior rooms were lit 12 hours daily with a temperature range of 21°C to 24°C and a relative humidity of 50 to 60%. Carbon dioxide assimilation of these plants after being placed indoors was monitored for 10 days.

2. Characteristics Related to *Ficus benjamina* Adaptation to an Interior Low Light Level. Rooted cuttings were potted singly in 20-cm diameter containers filled with Vergo Mix A and grown in a shadehouse with a light level of 300 µmol/m^2/s. Each container was topdressed with 7 g of an eight-month formulation Osmocote 17-7-12 and watered two to three times a week. After one year of growth, uniform plants were selected, and leaf areas, specific leaf areas, leaf thickness, internode lengths, and chlorophyll contents of 40 fully expanded mature leaves were measured. The plants were then placed in interior evaluation rooms under a light intensity of 16 µmol/m^2/s. One year after indoor placement, leaf and specific leaf areas, leaf thickness, internode lengths, and chlorophyll contents of 40 fully expanded mature leaves produced indoors were measured.

Variegated Foliage Plant: *Dieffenbachia maculata* 'Camille'

Tissue-culture liners of *Dieffenbachia maculata* 'Camille' were potted singly in 15-cm diameter containers filled with Vergo Mix A. Potted plants were placed on ebb-and-flow trays and fertigated with a solution made from a water-soluble fertilizer 17N-2.1P-15.7K (Peter's 24N-8P_2O_5-16K_2O, Grace-Sierra Horticultural Products, Milpitas, CA) containing 200 ppm N twice a week through subirrigation as described by Chen et al. (2003). Plants were grown in a shaded greenhouse with a light intensity of 300 µmol/m^2/s. Four months after transplanting, plants attained marketable sizes. Five uniform plants were selected and the third mature leaf from the meristem of each plant was excised and percentages of leaf variegation were quantified via digital scanning and computerized pixel counting. Immediately after variegation quantification, ten 0.3 cm^2 discs were punched from green and yellow-white areas of the leaf and extracted with 5 ml dimethyl sulphoxide for 30 min in a water bath at 65°C (Richardson et al., 2002). Chlorophyll absorbance was determined using a spectrophotometer (SmartSpec 3000, Bio-RAD Laboratories, Hercules, CA) at 645 nm and 663 nm and chlorophyll concentrations were calculated. Leaf thickness, petiole length, and ratio of canopy width to height were also determined. Canopy width to height ratio was calculated based on an equation of (width 1 + width 2)/2 ÷ height; where width 1 equals the cm across at widest point and width 2 equals a measure at a 90° rotation from width 1 (Chen et al., 1999). The five plants were placed into interior rooms under 16 µmol/m^2/s for evaluation. Four months after indoor placement, growth parameters, variegation, and chlorophyll contents of the third leaf produced after placement indoors was measured.

Flowering Foliage Plants: *Anthurium* × 'Red Hot'

1. *Pn* of Individual Leaves in Shaded Greenhouse and Interior Conditions. Tissue cultured liners of *Anthurium* × 'Red Hot' (Henny, 1999) were potted in 15-cm diameter containers filled with Vergo Mix A and grown in a shaded greenhouse with a light level of 300 µmol/m^2/s. Each container was topdressed with 5 g of an eight-month formulation Osmocote 17-7-12 and watered twice a week. The main shoot leaves were numbered as one to five with one as the youngest expanded leaf. After measuring the *Pn* of each leaf, five plants were maintained in the shaded greenhouse and the other five were placed in interior rooms under a light intensity of 16 µmol/m^2/s. The *Pn* of each leaf of plants in both locations were measured daily for 17 days.

2. Responses to Interior Low Light Conditions. Tissue cultured *Anthurium* × 'Red Hot' liners were potted in 15-cm diameter containers filled with Vergo Mix A and cultured in a shaded greenhouse as described above. Plants flowered eight months after transplanting. Number of new leaves, senesced leaves, flower count, senesced flowers, flower longevity, and ratio of canopy widths to heights were determined monthly. Three months later, the plants were paced in interior evaluation rooms with a light intensity of 16 µmol/m^2/s. Plant canopy width to height ratios, numbers of new leaves, senesced leaves and flowers, and new flowers were recorded monthly after placement indoors. Flowers with any

discoloration on either spadix or spathe were considered senesced flowers.

Data Analysis

Statistical analyses were made using SAS (SAS Institute Inc., Cary, NC), using *t*-test, to determine differences.

RESULTS AND DISCUSSION

***Ficus benjamina* 'Common'**

Plants initially grown in 50 µmol/m^2/s adapted to the interior low light level much quicker than those initially grown in 100 and 300 µmol/m^2/s (Fig. 1). *Ficus benjamina* 'Common', the most popular interiorscaping tree, was extremely sensitive to changes in environments. This sensitivity was reflected by the inability to promptly establish a positive net photosynthesis rate (*Pn*) under indoor conditions. As a result, leaves dropped and aesthetic value decreased. Results also showed that in order to establish *Pn* indoors, *Ficus benjamina* 'Common' should be grown initially or acclimatized later under quite low light levels.

Ficus benjamina 'Common' responded to interior low light by enlarging leaf area, reducing leaf thickness, increasing specific leaf area, and increasing internode length to intercept more light (Table 1). Chlorophyll b increased, and correspondingly the chlorophyll a to b ratio was decreased. This result supports the findings that shade tolerant plants have a low a/b ratio (Luttge, 1997).

***Dieffenbachia maculata* 'Camille'**

Response of *D. maculata* 'Camille' to interior low light included a reduction in leaf area, decrease of leaf thickness, increase of petiole lengths, and increase of canopy width to height ratio. The latter increased light interception (Table 2). The most pronounced change was the decrease of variegation. Percentages of green color accounted for only 18.8% (and thus yellow-white for 81.2%) of the third leaf at the end of production. Six months after being indoors at 16 µmol/m^2/s, green color increased to 77.5%. Chlorophyll a, b, and a/b ratios in green areas of the third leaf produced in the greenhouse were not significantly different from those in plants produced indoors (Table 3). However, chlorophyll a and b in the yellow-white areas of the third leaf in plants that were indoors increased about 6 times compared to those held in a greenhouse. In these areas no difference in chlorophyll a/b ratio was detected.

***Anthurium* × 'Red Hot'**

Individual leaves of *Anthurium* × 'Red Hot' varied in *Pn*. In general, the most recently fully expanded leaf had the highest *Pn* regardless of indoor or greenhouse conditions (Fig. 2). All leaves retained levels of *Pn* after placement indoors under 16 µmol/m^2/s. The oldest leaf maintained a *Pn* comparable to all leaves except the youngest expanded leaf, under the interior conditions. These responses contrast with those in *Ficus*, which, after indoor placement, exhibited a low *Pn* for 3-10 days depending on light levels during production. When placed indoors, *Anthurium* leaves had a much higher *Pn* than *Ficus* leaves.

It is noteworthy that the reduction of *Pn* in *Anthurium*'s oldest leaf was much less than that of the other leaves. Old leaf senescence under indoor conditions significantly decreased compared to that in the production phase (Table 4). It is possible that older *Anthurium* leaves may be triggered to rejuvenate or gain photosynthetic activity indoors when subjected to reduced light levels. *Anthurium* × 'Red Hot' was able to produce new leaves and new flowers in the interior conditions (Table 4). On an average, it maintained 2.7 flowers monthly for six months at the light level of 16 µmol/m^2/s.

In summary, this study revealed that mechanisms underlying tolerance to interior low light levels vary widely among representatives of the three groups of foliage plants. *Ficus benjamina* 'Common', a green-leafed plant, adapted to indoor conditions by

increasing specific leaf area, internode length, and chlorophyll b content for more light capture. The data indicate that *Ficus benjamina* 'Common' should either be produced under low light or acclimatized under a low light level before placing in indoor conditions. Adaptation of *Dieffenbachia maculata* 'Camille', which has variegated leaves, included decreases in leaf area and foliar variegation and an increase in both chlorophyll a and b content in the variegated area of the leaves. *Anthurium* × 'Red Hot', a flowering foliage plant, showed better adaptation to low light levels as it was able to sustain similar levels of net photosynthetic activity, and maintaining 2 to 3 flowers constantly over a six-month period. *Anthurium* and *Dieffenbachia* also changed overall morphology by increases in canopy width to height ratio, which will intercept more light.

ACKNOWLEDGEMENTS

Florida Agricultural Experiment Station journal series no. R-09729. This research was supported in part by the National Foliage Foundation. The authors thank Kelly Everitt for critical reading of this manuscript.

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Tables

Table 1. Morphological characteristics and chlorophyll contents of *Ficus benjamina* 'Common' at the end of production in a shaded greenhouse under 360 μmol/m^2/s and 12 months after placement indoor under a light level of 16 μmol/m^2/s.

Light level (μmol/m^2/s)	Leaf area (cm^2)	SLA[z] (cm^2/g)	LT[y] (mm)	IL[x] (cm)	Chl a (mg/cm^2)	Chl b (mg/cm^2)	Total chl (mg/cm^2)	Chl a/b
300	18.9	43.1	0.2	3.4	0.018	0.004	0.022	4.50
16	23.0	64.5	0.15	4.4	0.019	0.006	0.025	3.17
Significance[w]	*	**	*	*	ns	**	ns	**

[z]Specific leaf area; [y]leaf thickness; [x]internode length.
[w]ns, *, and ** indicates nonsignificance and significance at 5% and 1% level by *t-test*.

Table 2. Morphological characteristics of *Dieffenbachia maculata* 'Camille' at the end of production in a shaded greenhouse under a light level of 300 μmol/m^2/s and six months after placement indoor at a light level of 16 μmol/m^2/s.

Light level (μmol/m^2/s)	Leaf area (cm^2)	LT[z] (mm)	PL[y] (cm)	W/H[x]	Dark green[w] (%)	Light green[w] (%)
300	122.9	0.27	4.4	1.2	18.8	81.2
16	84.3	0.24	2.6	1.7	77.5	22.5
Significance[v]	*	ns	*	*	**	**

[z]Leaf thickness; [y]petiole length; [x]canopy width to height ratio; [w]percentage of green and yellowish light color of the fully expanded leaf.
[v]ns, *, and ** indicates nonsignificance and significance at 5% and 1% level by *t-test*.

Table 3. Chlorophyll contents (mg/cm^2) in green and yellow-white areas of *Dieffenbachia maculata* 'Camille' at the end of production in a shaded greenhouse under a light intensity of 300 μmol/m^2/s and six months after placement indoor under a light level of 16 μmol/m^2/s.

Light level	Green				Yellow-white			
(μmol/m^2/s)	a	b	Total	a/b	a	b	Total	a/b
300	0.036	0.015	0.051	2.36	0.0016	0.0008	0.0024	2.44
16	0.034	0.013	0.048	2.59	0.0119	0.0046	0.0165	2.58
Significance[z]	ns	ns	ns	ns	*	*	*	ns

[z]ns, *, and ** indicates nonsignificance and significance at 5% and 1% level by *t-test*.

Table 4. Morphological characteristics of *Anthurium* × 'Red Hot' at the end of production in a shaded greenhouse under maximum light level of 300 μmol/m^2/s and six months after placement indoor under a light level of 16 μmol/m^2/s.

Light level (μmol/m^2/s)	New leaf No.	Leaves senesced	Flower counts	Senesced flowers	Flower longevity	W/H ratio[z]
300	4.34	1.75	7.67	2.32	30.5	1.34
16	2.32	0.67	3.68	0.65	32.5	1.92
Significance[y]	**	**	**	**	ns	*

[z]Canopy width to height ratio.
[y]ns, *, and ** indicates nonsignificance and significance at 5% and 1% level by *t-test*.

Figures

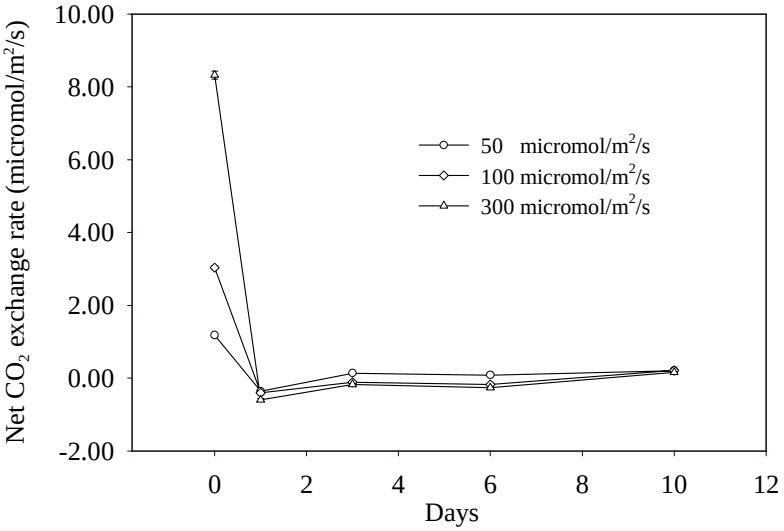

Fig. 1. Change in net CO_2 exchange rate of *Ficus benjamina* 'Common' before and after placement from greenhouse (50, 100, 300 micromol/m^2/s) to interior rooms (16 micromol/m^2/s).

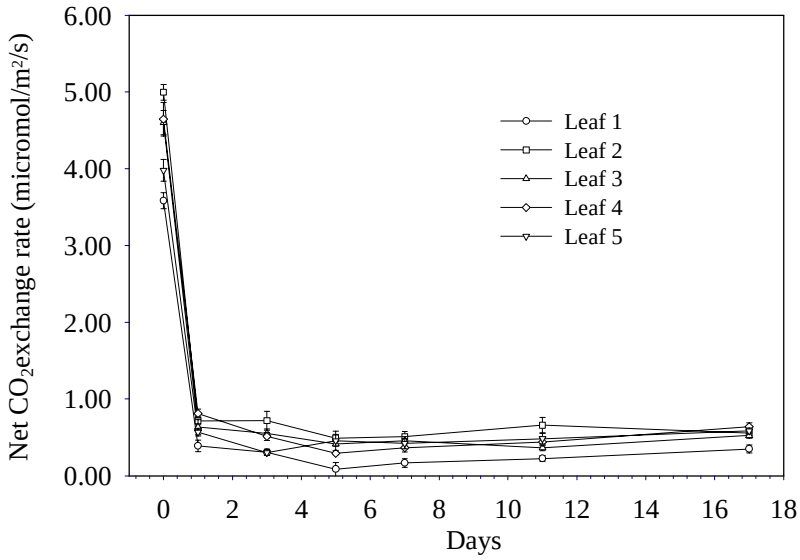

Fig. 2. Change in net CO_2 exchange rate of *Anthurium* × 'Red Hot' before and after placement to interior rooms (16 micromol/m^2/s) from greenhouse (300 micromol/m^2/s).