COLORADO GREENHOUSE GROWERS ASSOCIATION, INC.

Research Bulletin

Bulletin 360
Edited by David E. Hartley
June 1980

# MINIMUM LIGHT INTENSITIES FOR THREE FOLIAGE PLANTS[1]

R.G. Pass and David E. Hartley[2]

Increased use of foliage plants for interiors has intensified concern for proper acclimatization to enhance their survival in new environments. Acclimatization refers to the climatic adaptation of an organism (plant) to a new environment (5); specifically, moving a foliage plant from the optimum conditions of greenhouse production to the limiting conditions of an interior environment. Research (3, 4) has shown that acclimatization prior to placement indoors is beneficial to most foliage plants. The length of acclimatization as well as the type of acclimatization varies for specific foliage plants.

Photosynthetically active radiation (PAR) in the 400-700 nm region is the most important factor in foliage plant acclimatization. Interior environments have low light intensities which places limitations on plants, both physiologically and metabolically (7). In order to survive these limitations, plants must adapt to these low PAR levels (1).

Previous work at Colorado State University, DePauw & DePauw (Unpublished data 1975), has shown that there is marked variation among plants within a species which can be attributed to the previous history of the plants. Secondly, plants grown under high levels of PAR have higher light compensation points than plants grown low PAR levels. And thirdly, if plants are moved from high PAR to low PAR, a period of time is required for acclimatization before a new and lower light compensation point is reached, the light compensation point being the PAR level at which there is no net exchange of $CO_2$, or the point at which photosynthesis and respiration are essentially equal (13).

This study was undertaken to determine the rate and extent to which foliage plants grown in a greenhouse environment adapt to low PAR levels of interior environments.

## Materials and Methods

Commercially salable plants in 15.2 cm pots were received March, 1977. Vegetatively produced *Nephrolepis exaltata* 'Bostoniensis' (Boston fern) and *Epipremnan aureum* and seed propagated *Brassaia actinophylla* (umbrella tree) were selected for their economic importance and taxonomic diversity. The potting media consisted of 1 part Canadian peat and 1 part #8 perlite. Each plant received a top dressing of 14g of a slow release fertilizer (14N—6.0P—11.6K) upon arrival. All plants were grown in a fiberglass-covered, air cooled greenhouse until the start of the light acclimatization experiments on July 7, 1977. The mean of maximum irradiation during this pretreatment period was 931 $\mu E \cdot m^{-2} \cdot sec^{-1}$.

Twelve plants of each species were selected for uniformity at experiment initiation. All remnants of slow-release fertilizer applied in March were removed, pots leached thoroughly and no additional fertilizer supplied to plants through the duration of the experiment.

A system to measure the rate of net $CO_2$ exchange for whole plants was designed to determine light compensation points and acclimatization rates. The system consisted of 2 distinct parts: 1) light acclimatization chambers which contained the foliage plants and their replicates, and sample chambers (Fig. 1) and 2) the infrared gas analysis system.

[1]Reprint from Vol. 104(6). November 1979, *Journal of the American Society for Horticultural Science,* Alexandria, Virginia 22314.

[2]Graduate research assistant and associate professor respectively. The paper is a part of a M.S. thesis submitted by the senior author. Supported in part by a grant from the Fred C. Gloeckner Foundation, and the Colo. State Univ. Expt. Station, and published as Scientific Series Paper No. 2347.

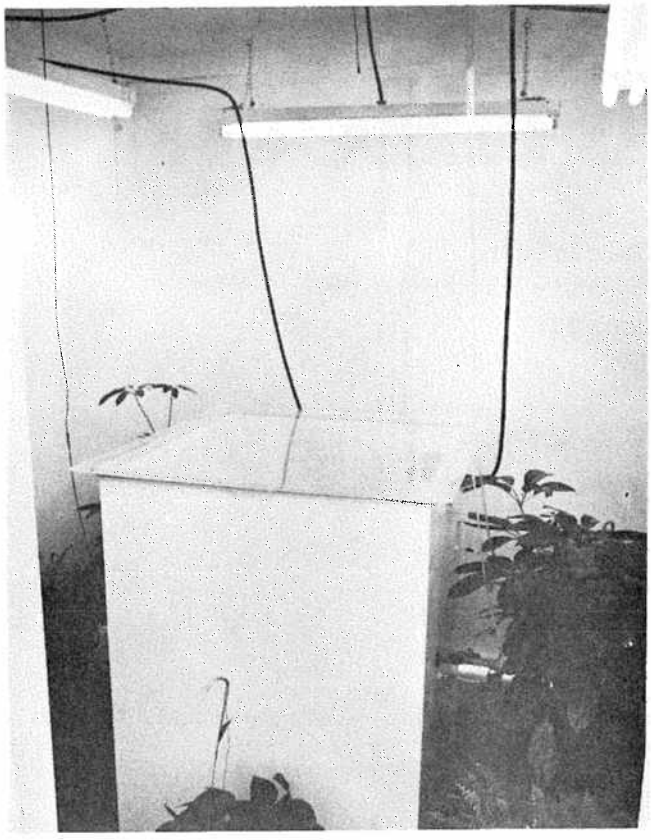

Figure 1: A closed system sample chamber within a light acclimatization chamber for the measurement of net $CO_2$ exchange rates for whole plants under low irradiation levels.

Walk-in light acclimatization chambers were built to create an isolated, fixed irradiation level, and to accommodate 9 whole plants (3 replications of 3 species) and the sample chamber. The irradiation source consisted of 4 double-tubed 40 Watt, Cool White, fluorescent fixtures and one 250 Watt, high pressure sodium lamp. Different irradiation levels in the chambers were accomplished by raising and lowering the fixtures and covering them with cheese cloth screens. Irradiation levels of 14, 29, 38, and 70 $\mu E \cdot m^{-2} \cdot sec^{-1}$ PAR were maintained for 14 hr daily. Chamber temperatures were maintained at 25° C ± 2.

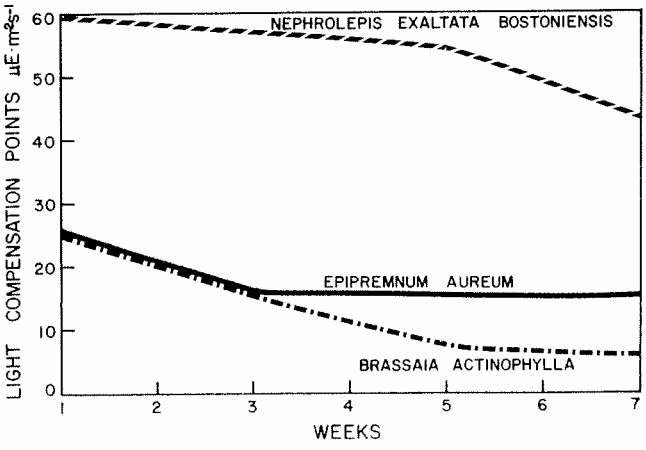


Figure 2. Rates of acclimatization for *Brassaia actinophylla*, *Nephrolepis exaltata* 'Bostoniensis', and *Epipremnum aureum*.

The closed system sample chambers were constructed to obtain net $CO_2$ exchange rate for whole plants. Two small fans were mounted on different planes on adjacent sides of the sample chamber to create a homogenous $CO_2$ concentration. Ambient air temperatures within the light acclimatization chambers were responsible for temperature control of the sample chambers.

A differential infrared gas analyzer (IRGA) was used for all measurements of $CO_2$ exchange. Calibration checks were made at regular intervals using standard $CO_2$ in nitrogen. A flow rate of 420 ml/min was maintained from the sample chamber to the IRGA. The air sample from the sample chamber passed through a condensation trap, dew point sensor and dryer before analysis by the IRGA and returned to the same chamber. Chambers were connected to a solenoid valve system allowing sample gas from the appropriate sample chamber to be removed and returned on a timed basis.

Rates of net $CO_2$ exchange were measured by placing the replicated species in the closed system sample chamber in each of the light acclimatization chambers. The rate of $CO_2$ exchange was determined from the $CO_2$ increase or decrease in concentration for each chamber. Net $CO_2$ measurements were made on each plant 3 times a week for the 7 week duration of the experiment. The 3 weekly $CO_2$ measurements were averaged to give a mean net $CO_2$ exchange rate for weeks 1, 3, 5, and 7.

An attempt was made to measure root and soil respiration. Three replications of each species with all the photosynthetic area removed, were utilized for these measurements. The mean rate of respiration for the 3 species was about 0.03 mg $CO_2 \cdot pot^{-1} \cdot hr^{-1}$. An HSD mean separation test for these means showed no significant differences (P=5%).

Total leaf area was determined for each plant utilizing a portable leaf area meter. This permitted non-destructive, intact leaf area measurements.

All photosynthetic and respiratory rates determined for the experiment were computed by the equation (2):

$$P_n \text{ or } R_d = ((MVT_1P/LTP_1)\ (ppm/hr \times 10^{-6}))/LA$$

where:
- $P_n$ = net photosynthesis (mg $CO_2 \cdot dm^{-2} \cdot hr^{-1}$)
- $R_d$ = dark respiration (mg $CO_2 \cdot dm^{-2} \cdot hr^{-1}$
- M = mole weight of $CO_2$ (44,010 mg)
- V = volume of closed system (804.2 1)
- $T_1$ = 273° K
- $P_1$ = average barometric pressure (635 mg Hg)
- L = mole volume of $CO_2$ (22.414 1)
- T = 398° K
- $P_1$ = standard barometric pressure (760 mg Hg)
- ppm/hr = $CO_2$ exchange rate in parts per million per hr converted to the volume fraction of $CO_2$ by multiplying by $10^{-6}$
- LA = leaf area of one side ($dm^2$)

Computed net $CO_2$ exchange rates at the 4 irradiation levels were subjected to linear regression analysis by species and an equation for each resulting line was obtained using the formula (7):

$y = B_1x + B_0$, where:
- y = net $CO_2$ exchange rate
- x = irradiance
- $B_1$ = slope
- $B_0$ = y-intercept

Light compensation points were computed by substituting y = 0 into the equation and solving for x, the resulting formula for the light compensation points being $x = B_0/B_1$ (7).

The experiment was treated as a split plot in design with species being main plots and acclimatization time as subplots. Analysis of variance was then performed on the net $CO_2$ exchange rates. When significant F-values were found, a Tukey's HSD mean separation test was used to determine significant differences (P=5%) among means.

## Results

All 3 species exhibited net $CO_2$ exchange rates that decreased with decreasing levels of PAR (Table 1). At 70 $\mu E \cdot m^{-2} \cdot sec^{-1}$ of PAR there was always net $CO_2$ uptake over the 7 week period. However, the net amount of $CO_2$ fixed consistently decreased over the 7 weeks. At the lowest PAR level, 14 $\mu E \cdot m^{-2} \cdot sec^{-1}$, the $CO_2$ evolution diminished over the duration of the experiment. The $CO_2$ fixation, $CO_2$ evolution, and dark respiration rates were always greater during the first week of acclimatization (Tables 1 & 2).

Net $CO_2$ uptake for *Brassaia actinophylla* occurred at all PAR levels except for week one at 14 $\mu E \cdot m^{-2} \cdot sec^{-1}$ (Table 1). Although $CO_2$ uptake decreased over the course of the experiment, the rates were greater during the first week than during the following weeks. Dark respiration and consequential $CO_2$ evolution also diminished at all PAR levels during the experiment (Table 2). Dark $CO_2$ evolution decreased during weeks 1, 3 and 5 but no reduction occurred during the seventh week.

Net $CO_2$ uptake for *Nephrolepis exaltata* 'Bostoniensis' occurred at 70 $\mu E \cdot m^{-2} \cdot sec^{-1}$ PAR $CO_2$ evolution took place at the lower PAR levels and was greater for weeks 1 and 3. $CO_2$ evolution decreased to week 5 and then leveled off. A large reduction in dark respiration occurred between weeks 1 and 3 but did not change for the rest of the experiment (Table 2).

$CO_2$ fixation for *Epipremnum aureum* took place at a diminishing rate for PAR levels 29, 38, and 70 $\mu E \cdot m^{-2} \cdot sec^{-1}$ (Table 1). $CO_2$ evolution resulted at the lowest irradiation level, 14 $\mu E \cdot m^{-2} \cdot sec^{-1}$. Less $CO_2$ was evolved during weeks 3, 5 and 7 than during week one. Dark respiration rates were lower for this species during week one, but, like the other species, also decreased during weeks 3 and 5 at all PAR levels (Table 2).

*Brassaia actinophylla* exhibited the most dramatic reduction in light compensation points of the 3 species tested (Fig. 2) where a 5-fold reduction in the light compensation point between week 1 and 7 occurred. *Nephrolepis exaltata* 'Bostoniensis' exhibited the highest light compensation points with a 1.4 fold reduction from week 1 to week 7 and the slowest rate of acclimatization. *Epipremnum aureum* was intermediate in acclimatization rate with a 1.7 fold reduction in light compensation points from week 1 to 7.

## Discussion

Results of net $CO_2$ exchange and dark respiration demonstrated that *Brassaia actinophylla* was capable of the greatest photosynthetic efficiency at low PAR; *Epipremnum aureum* was intermediate, and *Nephrolepis exaltata* 'Bostoniensis' had the lowest photosynthetic efficiency. The changes that occurred during the process of acclimatization appeared to be caused by the plants' ability to photosynthesize more efficiently, with a reduction in respiration rates.

Increased photosynthetic efficiency may in part have resulted from changes in leaf morphology (6, 13). Older leaves of some species produced under high PAR may have improved photosynthetic efficiency at low PAR by increased chlorophyll production or reorientation of chloroplasts. New leaves produced under low PAR levels may have been larger, providing more surface area for maximum energy interception or chloroplasts might have oriented for maximum energy capture.

$CO_2$ evolution in the dark for the 3 species was significantly reduced during the 7 weeks of acclimatization. Reports in the literature indicate that plants grown in shade have lower respiration rates than those grown in exposed habitats (7, 8, 9, 10, 11, 12). McCree (10, 11) suggested that dark respiration could be characterized as having both maintenance and growth components. During acclimatization, the evident reduction in dark respiration may result from the change in relative importance of its 2 components, where the lower maintenance component was responsible for greater efficiency at the lower irradiation levels.

Table 1: Mean net $CO_2$ uptake or evolution at four PAR levels for plants acclimatized after 1, 3, 5 and 7 weeks.

| | | $CO_2$ uptake (+) or evolution (-) ($mg\ CO_2 \cdot dm^{-2} hr^{-1}$) | | | |
|---|---|---|---|---|---|
| | | PAR levels ($\mu E \cdot m^{-2} \cdot sec^{-1}$) | | | |
| Species | Weeks | 14 | 29 | 38 | 70 |
| *Brassaia actinophylla* | 1 | -0.85a[z] | +1.11a | +1.80a | +8.11a |
| | 3 | +0.15b | +0.45b | +0.95b | +2.70b |
| | 5 | +0.20b | +0.48b | +0.82b | +1.96b |
| | 7 | +0.15b | +0.38b | +0.65b | +1.40b |
| *Nephrolepis exaltata* 'Bostoniensis' | 1 | -3.00a | -2.28a | -1.70a | +0.82a |
| | 3 | -2.01a | -1.21a | -1.03a | +0.67a |
| | 5 | -0.64b | -0.57b | -0.32b | +0.10b |
| | 7 | -0.13b | -0.07b | +0.03b | +0.10b |
| *Epipremnum aureum* | 1 | -1.27a | +0.62a | +1.56a | +4.81a |
| | 3 | -0.17b | +0.58b | +1.24b | +3.26b |
| | 5 | -0.15b | +0.44b | +0.98b | +1.02b |
| | 7 | -0.04b | +0.13b | +0.19b | +0.79b |

[z]Mean separation for species in columns by Tukey's HSD test, 5% level.

Table 2: Mean dark respiration rates which represents $CO_2$ evolution in mg $CO_2 \cdot dm^{-2} \cdot hr^{-1}$ at four PAR levels for plants acclimatized after 1, 3, 5 and 7 weeks.

| Species | Weeks | $CO_2$ evolution (mg $CO_2 \cdot dm^{-2} \cdot hr^{-1}$) PAR levels ( $\mu E \cdot m^{-2} \cdot sec^{-1}$) 14 | 29 | 38 | 70 |
|---|---|---|---|---|---|
| *Brassaia actinophylla* | 1 | -5.61a[z] | -6.24a | -6.46a | -6.00a |
| | 3 | -1.97b | -2.77b | -2.93b | -3.83b |
| | 5 | -1.25c | -1.16c | -1.31c | -1.74c |
| | 7 | -1.20c | -0.98c | -1.17c | -0.86c |
| *Nephrolepis exaltata* 'Bostoniensis' | 1 | -5.47a | -5.30a | -5.60a | -5.74a |
| | 3 | -1.95b | -2.20b | -2.22b | -2.11b |
| | 5 | -1.30b | -1.47b | -1.38b | -1.79b |
| | 7 | -1.18b | -1.19b | -1.03b | -1.13b |
| *Epipremnum aureum* | 1 | -3.19a | -3.21z | -4.00a | -4.42a |
| | 3 | -2.90b | -2.39b | -2.41b | -3.52b |
| | 5 | -1.12c | -1.15c | -1.74c | -2.59c |
| | 7 | -1.09c | -1.04c | -1.13c | -1.44c |

[z]Mean separation for species in columns by Tukey's HSD test, 5% level.

In an effort to explain the differences in light compensation points, McCree (11) gave evidence that the maintenance component of respiration dominated at the lower irradiation levels, and decreased with lowering of the irradiation to a minimum level. The light compensation point is a function of the photosynthesis-to-respiration ratio. By lowering the acclimatization irradiance, the maintenance respiration component is lowered allowing for efficient photosynthetic fixation of $CO_2$ at that new low PAR level. However, plants will reach a minimum PAR level which is dependent on plant species and production history.

## Literature Cited


1. Boardman, N.K. 1977. Comparative photosynthesis of sun and shade plants. *Annu. Rev. Plant Physiol.* 28:355-377.
2. Brown, L.F. 1974. Photosynthesis of two important grasses of the shortgrass prairie as affected by several ecological variables. PhD Dissertation. Colo. State Univ., Fort Collins.
3. Conover, C.A. 1975. Acclimatization of foliage plants. *S. Florist & Nurseryman* 9(8):3-5.
4. _____ and R.T. Poole. 1975. Acclimatization of tropical foliage plants. *Florists' Rev.* 157(4069):39, 62-65.
5. _____ and _____. 1975. Growing acclimatized plants. *Fla. Foliage Grower* 12(9):1-7.
6. Cooper, C.S. and M. Qualls. 1967. Morphology and chlorophyll content of shade and sun leaves of two legumes. *Crop Sci.* 7:672-673.
7. Fonteno, W.C. 1976. Net $CO_2$ flux, light compensation points, and acclimation rates of selected foliage plants. PhD Dissertation. Texas A & M Univ., College Station.
8. Grime, J.P. 1965. Shade tolerance in flowering plants. *Nature* 228:1349.
9. Ludlow, C.J. 1967. Photosynthesis in shade and sun ferns. PhD Dissertation. Vanderbilt University, Nashville, Tennessee.
10. McCree, K.L. and J.H. Troughton. 1966. Prediction of growth rates at different light levels from measured photosynthesis and respiration rates. *Plant Physiol.* 41:559-566.
11. _____.1974. Equations for the rate of dark respiration of white clover and grain sorghum, as a function of dry weight, photosynthetic rate, and temperature. *Crop Sci.* 14:509-514.
12. Moss, D.N. 1966. Respiration in leaves in light and darkness. *Crop Sci.* 6:351-354.
13. Salisbury, F.B. and C. Ross. 1969. *Plant Physiol.* Wadsworth Publishing Co., Belmont, Calif.



Published by
Colorado Greenhouse Growers Association, Inc.
Dick Kingman, Executive Vice President
2785 N. Speer Blvd., Suite 230
Denver, Colorado 805211

**Bulletin 360**





Direct inquiries to:
Office of the Editor
Horticulture Department
Colorado State University
Fort Collins, Colorado 80523