Literature Cited

1. Bukovac, M.J. and S.W. Wittwer. 1957. Absorption and mobility of foliar applied nutrients. Plant Physiol. 32:428-435.

2. Fisher, E.G. and D.R. Walker. 1955. The apparent absorption of P and Mg from sprays applied to the lower surface of McIntosh apple leaves. Proc. Amer. Soc. Hort. Sci. 65:17-24.

3. Hull, H.M., H.L. Morton and J.R. Wharrie. 1975. Environmental influence on cuticle development and resultant foliar penetration. Bot. Gaz. 41:421-451.

4. Kannan, S. 1969. Factors related to iron absorption by enzymatically isolated leaf cells. Plant Physiol. 44:1457-1460.

5. Kobayaske, Y. and D.V. Maudsley. 1970. Practical aspects of double isotope counting. In The Current Status of Liquid Scintillation Counting, ed. E.D. Bransom, Grune and Stratton, Inc., New York.

6. Koontz, H. and O. Biddulph. 1957. Factors affecting absorption and translocation of foliar applied phosphorus Plant Physiol. 32:463-470.

7. Middleton, L.J. and J. Sanderson. 1965. The uptake of inorganic ions by plant leaves. J. Exp. Bot. 16:197-215.

8. Okuda, A. and Y. Yamada. 1962. Foliar absorption of nutrients. IV. The effect of some organic compounds on the absorption of foliar applied phosphoric acid. Soil Sci. Plant Nut. 8:147-149.

9. Paparozzi, E.T. and H.B. Tukey, Jr. 1979. Foliar uptake of nutrients by selected herbaceous ornamental and woody landscape plants. J. Amer. Soc. Hort. Sci. 104:843-846.

10. Reed, D.W. and H.B. Tukey, Jr. 1978. Effect of pH on foliar absorption of phosphorus compounds by chrysanthemum. J. Amer. Soc. Hort. Sci. 103:337-340.

11. Reed, D.W. and H.B. Tukey, Jr. 1978. Effect of pH on foliar absorption of rubidium compounds by chrysanthemum. J. Amer. Soc. Hort. Sci. 103:815-817.

12. Rutland, R.B. and M.J. Bukovac. 1968. Foliar absorption of iron by chrysanthemum as influenced by lime induced chlorosis. Proc. Amer. Soc. Hort. Sci. 93:569-575.

13. Schonherr, J. and M.J. Bukovac. 1972. Penetration of stomata by liquids. Dependence on surface tension, wettability, and stomatal morphology. Plant Physiol. 49:813-819.

14. Shafer, W.E. and D.W. Reed. 1986. The foliar absorption of potassium from organic and inorganic potassium carriers. J. Plant Nut. 9:143-157.

15. Silberstein, O. and S.H. Wittwer. 1951. Foliar application of phosphatic nutrients to vegetable crops. Proc. Amer. Soc. Hort. Sci. 58:179-190.

16. Volk, P. and C. McAnliffe. 1957. Factors affecting the foliar absorption of ^{15}N labelled urea by tobacco. Proc. Soil Sci. Soc. Amer. 18:308-312.

17. Wittwer, S.H. 1967. Foliar application of nutrients—Part of the chemical revolution in agriculture. Plant Food Rev. 2:11-14.

18. Yamada, Y., W.H. Jyung, S.H. Wittwer and M.J. Bukovac. 1965. Effects of urea on ion penetration through isolated cuticular membranes and ion uptake by leaf cells. Proc. Amer. Soc. Hort. Sci. 87:429-432.

19. Yamada, Y., H.P. Rasmussen and M.J. Bukovac. 1966. Penetration of organic compounds through isolated cuticular membranes with special reference to ^{14}C urea. Plant Physiol. 40:170-175.

The Effect of Light Quality and Fertility on Long Term Interior Maintenance of Selected Foliage Plants[1]

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Abstract

Ficus benjamina, F. stricta, Dieffenbachia amoena and *Brassaia arboricola* were used to determine the effects of light quality and fertility on long-term maintenance of foliage plants in low light. The following light regimes were tested to determine the effect of light quality: 1) 100% PAR (photosynthetically active radiation) from fluorescent, 2) 70% PAR from fluorescent plus 30% PAR from incandescent, and 3) 50% PAR from each of Gro-Lux and Gro-Lux Wide Spectrum fluorescent. All light intensities were standardized at a total of 20 $u\text{Em}^{-2}\text{s}^{-1}$ (149 ft-c) for 4 months then 14 $u\text{Em}^{-2}\text{s}^{-1}$ (104 ft-c) for 8 months. When total PAR was equalized between treatments, no light source consistently proved superior for maintenance of the plants for one year in the interior. Three fertilizer regimes were used to maintain the four species in the interior for three months at 20 $u\text{Em}^{-2}\text{s}^{-1}$ (149 ft-c) then for 9 months at 12 $u\text{Em}^{-2}\text{s}^{-1}$ (89 ft-c). The fertilizer regimes tested were 1) soluble fertilizer (Peter's 20-20-20) added wkly in the irrigation water weekly at 200 ppm N : 88 ppm P : 166 ppm K, 2) slow-release fertilizer (Osmocote 14-14-14, 3 month release) applied as a top dress every three months at 4.1 g/15 cm (6 in) pot (0.57 g N : 0.25 g P : 0.47 g K), and 3) an unfertilized control. At the end of one year the effects of fertilizer treatment were found to be minimal, with the soluble fertilizer treatment showing some improved response with several growth parameters.

Index words: *Ficus benjamina, Ficus stricta, Dieffenbachia amoena,* and *Brassaia arboricola,* fig, schefflera, dumbcane, interiorscaping

Introduction

Professional interiorscapers and homeowners are concerned with maintaining plants for extended periods in interior environments where plants are subjected to low light intensities. Cathey (2), in a review of light sources for horticultural crops, reported that plants may be maintained in the interior for extended periods at 9.0 watts per square meter (Wm^{-2}), approximately 300 foot-

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candles (ft-c), and recommended that light sources be chosen on the basis of plant response and operating efficiency. Optimum light intensity is the most important requirement for foliage plant longevity (4, 5, 7). Little is known about the combined effects of light quality and fertility on growth and quality of plants maintained in low light for extended periods of time. The purpose of this study was to determine the effects of light quality and fertility on long-term maintenance of selected foliage plants in a low light interior environment.

Materials and Methods

For the light quality experiment, *Ficus benjamina* Linn., *F. stricta* Miguel, *Brassaia arboricola* Endl., and *Dieffenbachia amoena* Bull. liners were potted one per 15 cm (6 in) plastic pot in a medium of peat : perlite (1:1 by vol) amended with 2.97 kg/m^3 (5 lb/yd^3) dolomite limestone, 0.44 kg/m^3 (0.75 lb/yd^3) $FeSO_4$, 2.97 kg/m^3 (5 lb/yd^3) gypsum and 74 g/m^3 (2 oz/yd^3) fritted trace element mix. The plants were acclimatized for eight weeks at 25 uEm^{-2}s^{-1} (186 ft-c) at plant height under 40 watt fluorescent cool white lights (7). At the end of the acclimatization period, plants were placed in a simulated interior environment for 12 months under 3 light treatments with 5 replications per treatment. The plants were fertilized weekly with 300 ppm N : 132 ppm P : 249 ppm K and leached monthly. Total photosynthetically active radiation (PAR at 400-700 nm) in each treatment was set initially at 20 uEm^{-2}s^{-1} (149 ft-c) for the first 4 months, then decreased to 14 uEm^{-2}s^{-1} (104 ft-c) for the remaining 8 months when no treatment differences were noted at the higher light intensity. Temperature averaged 22.7 $\pm$1.5°C (73 $\pm$2.7°F) and relative humidity averaged 54.3 $\pm$12.6%. The light treatments were 1) 100% of total PAR from 40 watt cool white fluorescent lights (Westinghouse), 2) 70% of total PAR from 40 watt cool white fluorescent lights (Westinghouse) and 30% of total PAR from 40 watt incandescent lights (Westinghouse), and 3) 50% of total PAR from each of 40 watt fluorescent Gro-Lux lights and Gro-Lux Wide Spectrum lights (Sylvania). Light was supplied for 12 hours per day from 0600-1800 hours. Light intensity at plant height was regulated by adjusting lamp height. Maintenance of equal PAR at plant height in each treatment assured that differences between treatments would be due to light quality effects and not light intensity differences between treatments. Chlorophyll was determined according to the procedure of Arnon (1).

For the fertility experiment, *F. stricta* and *D. amoena* liners were potted in peat : perlite (1:1 by vol) in 10 cm (4 in) pots, and *F. benjamina* and *B. arboricola* were potted in 15 cm (6 in) pots. All plants were acclimated in a greenhouse for 5 weeks under neutral shade at 150 uEm^{-2}s^{-1} (767 ft-c) measured at 1400 hours on a cloudless day. Plants were initially fertilized with 300 ppm N : 132 P : 249 K for the first 10 days to aid establishment, leached, then not fertilized again for the remainder of the 5 week acclimatization period. At the end of acclimatization, five plants for each treatment were placed in a simulated interior environment with 20 uEm^{-2}s^{-1} (149 ft-c) at plant height provided by 75 watt cool white fluorescent lights (Westinghouse) for 12 hours per day from 0800-2000 hours. At the end of 3 months, a flush of new growth occurred on many of the plants regardless of treatment, so the light level was lowered to 12 uEm^{-2}s^{-1} (89 ft-c) for the remaining 9 months. Temperature averaged 22.5 $\pm$1.5°C (72.5 $\pm$2.7°F). Fertilizer treatments for the study were 1) Peter's 20-20-20 in the irrigation water applied weekly at 200 ppm N : 88 ppm P : 166 ppm K, 2) Osmocote 14-14-14, 3 month release, at 4.1 g/15 cm (6 in) pot (0.57 g N : 0.25 g P : 0.47 g K per 15 cm pot) applied as a top dress every 3 months (4), and 3) an unfertilized control. Distilled water was used for all watering and fertilizer solutions and pots were leached monthly.

Results and Discussion

There were no significant differences ($p = 0.05$) between the three light sources on plant height, plant quality and leaf chlorophyll content for all four species, or on shoot fresh and dry weight for three of the four species (Table 1, Fig. 1). Some of the species showed enhanced response of some of the parameters measured, but no consistent trends were observed. *F. stricta* and *B. arboricola* were of good quality at the termination of the study, irrespective of treatment (Table 1). *D. amoena* in all treatments lost lower leaves throughout the study but continued to produce new leaves; some loss of variegation was noted in the plants under the Gro-Lux lights. *F. benjamina* performed the poorest of the four species, exhibiting an average of 21% leaf drop in all treatments. Collins and Blessington (3) and Peterson and Blessington (9) found less leaf drop and higher plant grade of *F. benjamina* after 10 weeks under incandescent lights compared to cool white fluorescent lights following 4-12 weeks dark storage, however, there was little difference between the light sources if the plants were given no previous dark storage.

Since few consistent differences were noted in the study due to light source at equal PAR, and therefore light quality, primary consideration for selection of a light source for interior usage should be given to light intensity and lamp characteristics, such as energy conversion efficiency, rated life, uniformity of light distribution, economics of operation and maintenance, and color rendition.

Fluorescent lights have been the standard light source for many years due to efficiency of operation, uniformity of light distribution, ease of maintenance and color rendition (2). Incandescent lights often are used to supplement fluorescent lights to enhance radiation in the

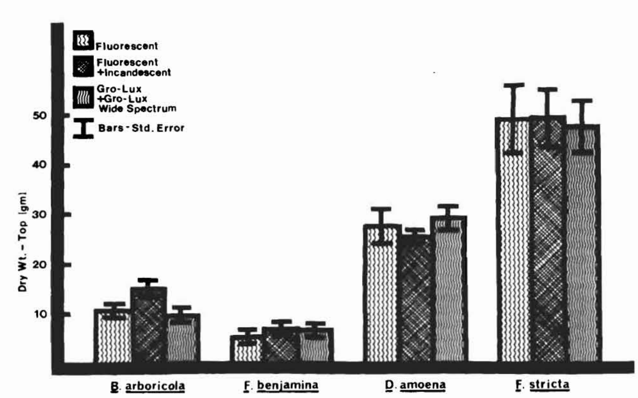

Fig. 1. Effect of light source on dry weight of plant shoots after maintenance in a simulated interior environment for four months at 20 uEm^{-2}s^{-1} (149 ft-c) then eight months at 14 uEm^{-2}s^{-1} (104 ft-c).

red and far red regions of the spectrum, which may be necessary for flowering responses and normal morphological development in some plants (2). However, the disadvantages of using incandescent lighting are the production of hot spots directly under the bulbs, which may damage plant tissue, and greater operating costs. Incandescent lights have an energy conversion efficiency of approximately 15% in the visible region of the spectrum and a rated life which is 6-7% of fluorescent lights (8).

An alternative to incandescent lights for supplemental far red light is the use of Gro-Lux fluorescent lights, which have additional fluorescing agents to enhance the red and far red regions of the spectrum. However, Gro-Lux lights have the disadvantages of higher cost, lower output intensity, a color rendition that gives a pink glow to human complexions, and decreased human visibility. For these reasons, Gro-Lux lights are best utilized for display lighting.

Because of these reasons, standard fluorescent lights may be the best interior light source for foliage plants. However, none of the light sources tested can be used for obtaining high light intensities unless they are placed relatively close to the plants. High intensity discharge lamps, such as high pressure sodium and metal halide lamps, are necessary to obtain greater intensity in large indoor areas or for placement at greater distances from the plants; but these light sources were not evaluated in this study.

Plants in the three fertilizer treatments showed few consistent trends in the growth parameters measured after one year in low light (Table 2, Fig. 2). *D. amoena* deteriorated under all treatments with a mean plant quality of 5 (1 best to 5 worst). *B. arboricola* and *F. stricta* were of good quality with or without fertilizer, but the soluble treatment significantly increased shoot fresh weight and dry weight and leaf number for both species. In addition, *F. benjamina* exhibited significant increases in shoot and root fresh and dry weight and leaf number due to the soluble fertilizer treatment.

Despite these differences in growth parameters, *F. benjamina, F. stricta* and *B. arboricola* all were of good quality at the termination of the study, regardless of treatment. No treatment yielded high quality *D. amoena* plants. Hence, the overall effects of fertilizer treatment on acclimatized plants after one year of low light were minimal. The low growth rate and low light intensity in the interior environment probably greatly reduced the plants' nutrient requirements, which was probably the reason for the minimal response to the fertilizer treatments. These findings agree with the results of Conover and Poole (5), who also found few differences between slow-release and liquid fertilization at low light intensities during a year long study. Conover *et. al.* (6) found a linear increase in chlorophyll with increasing rates of slow release fertilizer, but only a limited increase in plant quality after one year in the interior.

Significance to the Nursery Industry

These results indicate that in a low light interior environment light source and fertilizer regime, of the tested sources, had minimal effect on long term maintenance of foliage plants. Soluble fertilizers tended to enhance growth slightly in some species, however, either soluble or slow release fertilizers maintained good quality plants. Soluble fertilizers could be used when frequent leaching is possible to flush out excess salts from

Table 1. Effect of light quality on selected growth parameters, chlorophyll and quality of 4 species of foliage plants maintained at 20 $uEm^{-2}s^{-1}$ for **4 months then 14 $uEm^{-2}s^{-1}$ (104 ft-c) for 8 months.**

Treatment	% PAR	Height	Fresh Weight Shoot	Fresh Weight Root	Dry Weight Shoot	Dry Weight Root	Leaf Number	Leaf Area	Chlorophyll	Overall Quality[z]
		(cm)	(g)	(g)	(g)	(g)		(cm²)	(ug/cm²)	
F. benjamina										
Fluorescent	100	52.0a[y]	23.4a	6.0a	5.8a	1.3a	66.0b	15.5a	2.2a	4.0a
Fluor + Inc	70/30	56.0a	27.5a	4.1a	7.5a	1.7a	71.0ab	15.2a	1.6a	4.0a
Gro-Lux	50/50	51.5a	28.3a	5.0a	7.2a	1.2a	81.5a	17.5a	1.3a	3.0a
F. stricta										
Fluorescent	100	76.6a	154.3a	82.4ab	49.1a	12.1a	138.0b	29.9a	2.9a	3.0a
Fluor + Inc	70/30	76.0a	154.8a	92.8a	49.4a	13.0a	171.2a	31.7a	2.7a	2.4a
Gro-Lux	50/50	77.2a	142.5a	71.7b	48.0a	8.9b	146.2ab	32.9a	2.9a	2.4a
D. amoena										
Fluorescent	100	74.6a	424.1a	53.0b	27.7a	5.7a	9.0a	442.9ab	2.5a	4.4a
Fluor + Inc	70/30	78.0a	414.7a	75.2a	25.7a	6.2a	7.3a	401.5b	1.7a	4.5a
Gro-Lux	50/50	82.4a	476.8a	71.4a	29.4a	6.0a	8.2a	456.6a	2.2a	4.4a
B. arboricola										
Fluorescent	100	39.6a	99.2a	6.3a	11.6ab	1.2a	31.6a	75.0ab	1.0a	2.2a
Fluor + Inc	70/30	48.2a	110.6a	8.6a	15.0a	1.5a	30.0a	82.6a	1.3a	2.4a
Gro-Lux	50/50	37.2a	79.1b	6.1a	9.9b	1.2a	25.2a	61.9b	0.9a	2.6a

[z]Quality based on a scale of 1-5, where 1 = excellent to 5 = poor and unusable.

[y]Means between treatments within columns for each species followed by the same letter not significantly different at p = 0.05 by Duncan's multiple range test.

Table 2. **The effects of fertilizer treatments on selected growth parameters of 4 species of foliage plants maintained for 3 months st 20 $u\text{Em}^{-2}\text{s}^{-1}$ (149 ft-c) then 9 months at 12 $u\text{Em}^{-2}\text{s}^{-1}$ (189 ft-c).**

Treatment	Height	SHOOT		ROOT		Leaf Number	Overall Quality[z]
		Dry Wt.	Fresh Wt.	Dry Wt.	Fresh Wt.		
	(cm)	(g)	(g)	(g)	(g)		
F. benjamina							
Soluble	70.6a[y]	27.2a	96.1a	4.6a	21.4a	170.0a	1.2a
Slow Release	67.9a	23.4ab	77.1b	4.1a	18.0a	131.ab	1.4a
Control	65.6a	19.6b	60.6b	4.1a	16.6a	93.4b	2.4a
F. stricta							
Soluble	66.8a	30.5a	99.4a	5.5b	23.4ab	95.6a	2.0a
Slow Release	65.4a	22.4b	74.2b	5.0b	20.9b	67.4a	2.2a
Control	65.0a	27.6b	85.8b	8.2a	32.9a	74.6a	1.2a
B. arboricola							
Soluble	45.4a	12.0a	106.9a	1.0a	5.5a	62.0a	1.2a
Slow Release	44.3a	8.3b	77.8b	0.8a	4.5a	54.6a	1.4a
Control	42.7a	8.8b	77.1b	1.1a	2.7a	58.6a	2.0a
D. amoena							
Soluble	25.4a	3.2a	31.1a	0.4a	18.a	9.4a	5.0a
Slow Release	26.0a	3.2a	24.7b	0.6a	2.0a	11.8a	5.0a
Control	24.4a	2.0b	18.8b	0.3a	3.0a	5.2a	5.0a

[z]Quality based on a scale of 1-5, where 1 = excellent to 5 = poor and unusable.

[y]Means between treatments within columns for each species followed by the same letter are not significantly different at $p = 0.05$ by Duncan's multiple range test.

the constant fertilization. When leaching is impractical or labor costs are a consideration, slow release fertilizers could be used. Light source, hence light quality, did not consistently and significantly affect long term maintenance of foliage plants in low light interior environments, if sufficient light intensity was maintained. Therefore, when choosing a light source for interior usage, primary consideration should be given to light intensity and lamp characteristics, such as energy conversion efficiency, rated life, uniformity of light distribution, economics of operation and maintenance, and color rendition.

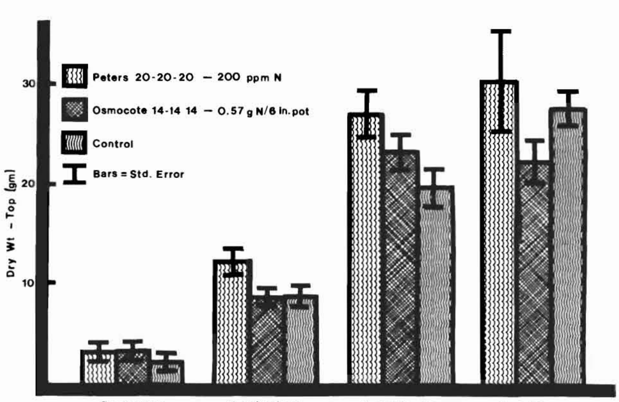

Fig. 2. **Effect of fertilizer treatments on dry weight of plant shoots after maintenance in a simulated interior environment for three months at 20 $u\text{Em}^{-2}\text{s}^{-1}$ (149 ft-c) then for nine months as 12 $u\text{Em}^{-2}\text{s}^{-1}$ (89 ft-c).**

Literature Cited

1. Arnon, D.I. 1949. Copper enzymes in isolated choroplasts; polyphenol-oxidase in *Beta vulgaris.* Plant Physiol. 24:1-15.

2. Cathey, H.M. 1980. Light and lighting systems. Hort. Reviews 2:491-537.

3. Collins, P.C. and T.M. Blessington. 1982. Postharvest effects of dark storage, light duration, and source on keeping quality of *Ficus benjamina* L. HortScience 17(6):906-908.

4. Conover, C.A. and R.T. Poole. 1977. Fertilization of indoor foliage plants. Proc. Nat. Trop. Foliage Short Course, pp. 130-133.

5. Conover, C.A. and R.T. Poole. 1981. Influence of light and fertilizer levels and fertilizer sources on foliage plants maintained under interior environments for one year. J. Amer. Soc. Hort. Sci. 106:571-574.

6. Conover, C.A., R.T. Poole and T.A. Nell. 1982. Influence of intensity and duration of cool white fluorescent lighting and fertilizer on growth and quality of foliage plants. J. Amer. Soc. Hort. Sci. 107(5):817-822.

7. Fonteno, W.C. and E.L. McWilliams. 1978. Light compensation points and acclimatization of four tropical foliage plants. J. Amer. Soc. Hort. Sci. 103:52-56.

8. Mpelkas, C.C. 1981. Light sources for horticultural lighting. Sylvania Elec. Prod. Engineer. Bul., 352 pp.

9. Peterson, N.C. and T.M. Blessington. 1981. Postharvest effects on dark storage and light source on keeping quality of *Ficus benjamina* L. HortScience 16(5):681-682.