# Factors Affecting Foliar Absorption of Nutrients by Selected Landscape and Herbaceous Plants[1]

**David Wm. Reed[2] and Harold B. Tukey, Jr.[3]**
*Department of Floriculture and Ornamental Horticulture*
*Cornell University*
*Ithaca, NY 14850*

## Abstract

Plants and solution properties affecting the absorption of double-labeled $^{86}Rb$ $^{33}P$-phosphate, pH 7.2, by chrysanthemum leaves were studied. Leaf age did not affect absorption greatly. Optimum concentration for maximum total absorption and efficiency of absorption of both Rb and P without leaf burn was 20-30 mM Rb phosphate. Urea and several structurally related compounds (acetamide, propionamide and Rb acetate) decreased Rb and P absorption due to formation of salt deposits. Of 18 commercially available surfactants tested at 0.1%, only one significantly increased P absorption and all significantly decreased Rb absorption; many were phytotoxic. Of a variety of 20 different herbaceous ornamental and woody landscape species tested for their efficiency of absorption, P absorption ranged from 0.2-39% and Rb absorption ranged from 0.2-42%; surfactants generally increased the absorption of P and Rb for those species with waxy, pubescent or otherwise hard-to-wet leaves.

**Index words:** phosphorus, rubidium, potassium, surfactant, plant nutrition

## Introduction

Foliar fertilization of mineral nutrients has received renewed interest in recent years. Foliar fertilization allows rapid absorption and quick plant response, utilizes less fertilizer and avoids soil fixation, leaching and run-off. Foliar applications are economically and practically feasible for greenhouse and nursery crops where other types of sprays routinely are applied (9), and especially are applicable were fertilizers can be added to overhead irrigation systems.

Many factors alter the effectiveness of foliar applied nutrients. Previous studies identified the most effective rubidium (used as a tracer for potassium) and phosphorus compounds and the effect of pH (10, 11). Dibasic rubidium phosphate, above pH 7.2, was absorbed the most efficiently. This study reports the effect of plant and solution properties in absorption of Rb phosphate by a variety of herbaceous ornamental and woody landscape plants.

## Materials and Methods

*Chrysanthemum morifolium* 'Giant #4 Indianapolis White' cuttings were rooted under mist, then grown hydroponically in sand under long-day greenhouse conditions for 2 weeks. Other treatment conditions have been described previously (10, 11). For treatment, the plants were placed in a controlled environment growth chamber at 21°C, 40-50% relative humidity and a 16 hour photoperiod of 440 $u\mathrm{Es}^{-1}\mathrm{m}^{-2}$ (400-700 nm).

Double-labeled $^{86}Rb$-rubidium $^{33}P$-phosphate, pH 7.2, dosing solutions were prepared by adding 10 $u$Ci $H_3{}^{33}PO_4$ (carrier-free) and 0.2 $u$Ci $^{86}RbCl$ (0.4-10 Ci/g Rb) per 20 $u$l of dosing solution. Rubidium has been shown to act as a qualitative tracer for K (11, 14). All solutions were 25 mM Rb phosphate, except in the concentration experiment, and were self-buffered at pH 7.2. At pH 7.2 ($pK_a = 7.2$), the solution contains 50% monobasic phosphate ($H_2PO_4^-$) and 50% dibasic phosphate ($HPO_4^{-2}$). Five plants per treatment were used. For application, 20 $u$l of dosing solution were applied to the most recently matured and fully expanded leaf from the stem tip of plants containing 7-8 leaves, except in the leaf age experiment. After a 48-hour absorption period, a 1-cm disk encompassing the treated area was removed and discarded. The remainder of the plant was ashed for 12 hour at 525°C, dissolved in 6 N HCl, heated to dryness, then dissolved in 1 N HCl. A sample aliquot was added to a cocktail of Triton X-100: toluene (1:1 by vol) containing 5 g/l PPO (2,5-diphenyloxazole) and 0.1 g/l POPOP (1,4-bis-2-(phenyloxazoly)benzene) and counted with a Beckman LS-350 liquid scintillation counter. The net count rate was corrected for background and the activity of $^{33}P$ and $^{86}Rb$ was separated with quench correction curves and simultaneous equations (5).

To test the effect of leaf age, plants were allowed to grow until 13 leaves developed, then the various aged leaves were treated. To test the time course of absorption and translocation, treated plants were harvested over a 120 hour (5 day) period and assayed for radioactivity in the various parts. The effect of concentration was tested by varying the concentration of Rb phosphate from 0-100 mM (0-22,870 ppm total concentration). The effect of 18 commercial surfactants was tested by adding 0.1% surfactant to the Rb phosphate solution. To test the effect of organic additives, 5, 15 and 25 mM urea, acetamide, propionamide and Rb ace-

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[2]Presently, Associate Professor, Department of Horticultural Sciences, Texas A&M University, College Station, TX 77843; address for reprint requests.

[3]Presently, Director, Center for Urban Horticulture, University of Washington, Seattle, WA 98195.

tate were added to the Rb phosphate solution. Absorption by 20 ornamental species was tested by applying Rb phosphate, with and without 0.1% Al 825 surfactant, to the most recently matured leaf of young established plants. To measure the phytotoxicity from various concentrations and surfactants, whole plants were sprayed with non-radioactive solutions to run-off once per day for three consecutive days under greenhouse conditions.

**Results and Discussion**

There was no significant effect of leaf age on absorption of Rb by chrysanthemum (Fig. 1). Similarly, Rutland and Bukovac (12) found no effect of leaf age on foliar absorption of iron by chrysanthemum. However, the younger leaves absorbed significantly more phosphate than the older leaves (Fig. 1). It has been generalized that absorption decreases with increasing leaf age, which has been attributed to greater cuticle development (3), but physiological factors might also be involved (4).

Absorption of both Rb and phosphate increased rapidly for the first 12-24 hours after application, followed by a more gradual increase (Fig. 2). There was also a steady transport out of the treated leaf and into other plant parts, with Rb appearing in the other plant parts slightly more rapidly than phosphate. This supports the classification of Rb and phosphate as mobile nutrients (1). These data indicate that within a few days a large amount of the foliar applied Rb and phosphate can be absorbed and transported throughout the plant to supply nutrients during periods of peak nutrient demand (growth flushes, flowering, fruit set and filling, etc.) or quickly overcome deficiency symptoms before sale.

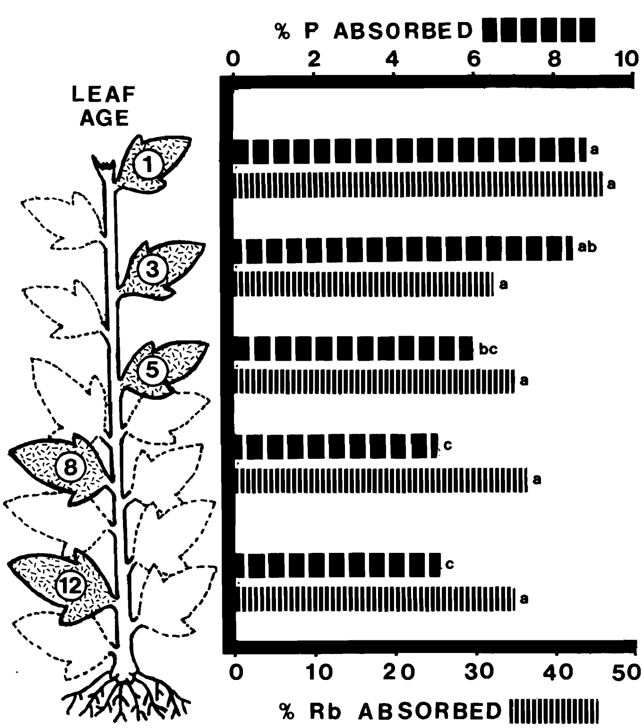


**Fig. 1. Effect of leaf age on absorption of 25 mM double-labeled $^{86}$Rb $^{33}$P-phosphate by chrysanthemum. For Rb and P, bars followed by the same letter are not significantly different at p = 0.05 by Duncan's Multiple Range Test.**

The total phosphate absorbed increased linearly with increasing concentration and the % phosphate absorbed reached a maximum at 20-40 mM, with decreased absorption above and below this range (Fig. 3). Koontz and Biddulph (6) found similar absorption of monobasic Na phosphate by beans in the range of 0.3-30 mM, except the % absorption reached a maximum at 10 mM. The total Rb absorbed increased linearly with increasing concentration, whereas the % absorption reached a maximum at 50 mM after which it decreased slightly (Fig. 3). Middleton and Sanderson (7) found similar results with cesium absorption by barley. Phytotoxicity studies with Rb phosphate revealed that repeated run-off applications of 30 mM or below did not cause leaf burn, whereas 40 mM or above caused leaf burn. This agrees with concentration ranges presented by Wittwer (17), although higher concentrations have been reported without leaf burn (15). Therefore, it appears that 20-30 mM Rb phosphate (approximately 4,574-6,861 ppm total concentration) was the optimal concentration because it yielded the highest total and efficiency of absorption without leaf burn.

Urea, acetamide and propioamide decreased both Rb and phosphate absorption, whereas Rb acetate in-

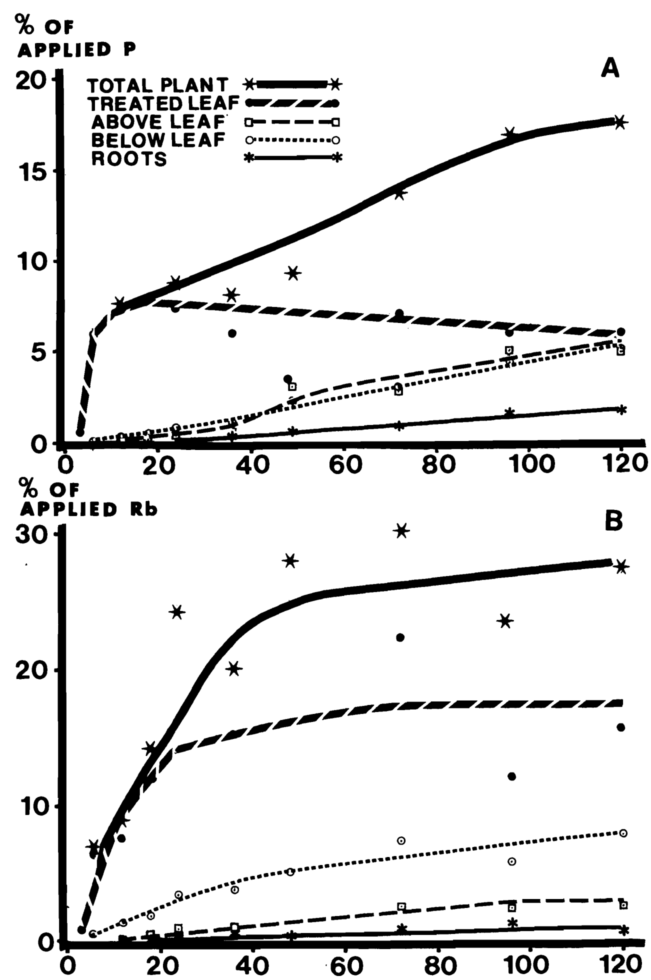


**Fig. 2. Time course of absorption and translocation of 25 mM double-labeled $^{86}$Rb $^{33}$P-phosphate by chrysanthemum.**

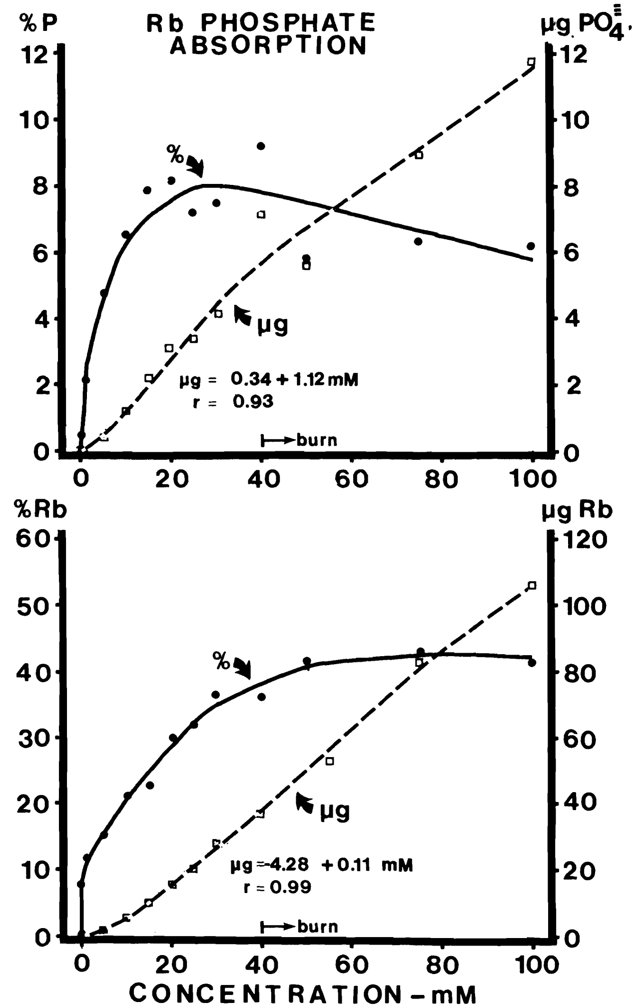


Fig. 3. Effect of concentration on total and percent absorption of 25 mM double-labeled $^{86}$Rb $^{33}$P-phosphate by chrysanthemum.

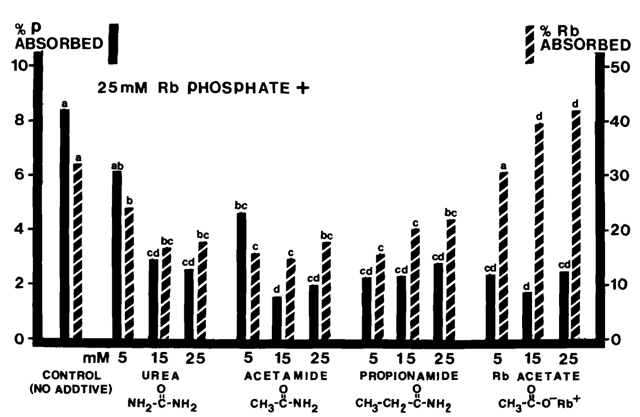


Fig. 4. Effect of organic additives on absorption of 25 mM double-labeled $^{86}$Rb $^{33}$P-phosphate by chrysanthemum. For Rb and P, bars followed by the same letter are not significantly different at $p = 0.05$ by Duncan's Multiple Range Test.

creased Rb absorption but decreased phosphate absorption (Fig. 4). Increased absorption of $^{86}$Rb-labeled K acetate also has been shown by Shafer and Reed (14). The urea/Rb phosphate solution formed a salt deposit on the leaf surface upon drying, which is probably the reason for the decreased absorption as was shown with other phosphate compounds by Reed and Tukey (10). Urea has been shown to be one of the most rapidly absorbed foliar applied nutrients (16), and has been speculated to alter cuticular permeability to enhance the absorption of other compounds (18, 19). In fact, urea and other organic compounds have been shown to increase the absorption of phosphate (2, 8). However, this study (Fig. 4) did not reveal enhanced absorption by urea and the other structurally related compounds tested.

Of the 18 commercial surfactants tested only AL 825 significantly increased phosphate absorption over the controls (Table 1). Ethomid 0/15 and Tween 85 enhanced phosphate absorption, but not significantly. The other surfactants were either without effect or decreased phosphate absorption. All surfactants tested significantly decreased Rb absorption compared to the controls. There was no correlation between the degree of absorption and ionic form or chemical class of the surfactants. The increased absorption of phosphate was not due to enhanced stomatal penetration, because mass flow through the stomatal pore also would have increased Rb absorption from the double-labeled solution. Further, Schonherr and Bukovac (13) have demonstrated that most surfactants do not lower surface tension sufficiently to allow stomatal penetration. Only 3 of the 18 surfactants tested were phytotoxic to old leaves, but 7 damaged the younger leaves (Table 1). There was no correlation between the degree of absorption and phytotoxicity.

From screening a wide variety of herbaceous and woody species, absorption of phosphate, without surfactant, ranged from 0.2% for *Codiaeum variegatum* var. *pictum* and *Pilea microphylla* to 38.7% for *Plectranthus australis* (Table 2). Absorption of Rb, without surfactant, ranged from 0.2% for *Codiaeum variegatum* var *pictum, Taxus media* and *Juniperus horizontalis* to 44.7% for *Pelargonium hortorum.* Generally, the herbaceous species had a higher degree of absorption while the more woody, pubescent or waxy-leaved species had a lower degree of absorption. When the surfactant AL 825 was added to the dosing solution, absorption of both Rb and phosphate increased in 10 species and decreased in 5 species. Except for *Chrysanthemum morifolium* and *Pilea cadierei,* Al 825 increased or decreased Rb and phosphate absorption in unison. Generally, AL 825 increased phosphate absorption by a larger magnitude than Rb absorption, and exhibited its greatest promotive influence on species with smooth, waxy foliage, such as *Impatiens, Begonia sempervirens-cultorum, Dianthus caryophyllus* and *Juniperus horizontalis,* or species with a pubescent leaf surface, such as *Rhododendron* 'Roseum Elegans.'

## Significance to the Nursery Industry

This study indicates that herbaceous ornamental and woody landscape plants differ greatly in their efficiency of foliar absorption. Generally, herbaceous species or species with easy-to-wet leaves exhibited the highest efficiency of absorption, while woody species or species with waxy, pubescent or hard-to-wet leaves exhibited a lesser efficiency of absorption. The effect of surfactants was very variable, and a positive response was dependent on the specific surfactant, nutrient and plant species. No single surfactant was effective under all conditions. Surfactants tended to be more effective on species with hard-to-wet leaves. Addition of urea to the solution did not enhance absorption. A concentration just below the level which causes leaf burn was the most effective to use.

**Table 1. Effect of surfactants on foliar absorption of 25 mM double-labeled $^{86}$Rb $^{33}$P-phosphate by chrysanthemum.**

| | Percent Absorbed[z] | | Phytotoxicity | |
|---|---|---|---|---|
| **Surfactant[y]** | **phosphate** | **Rb** | **old leaves** | **young leaves** |
| AL 825[2] | 18.9a | 23.9 bc | none | none |
| Ethomid 0/15[1] | 17.9ab | 24.5 b | slight | slight |
| Tween 85[2] | 11.9abc | 21.3 bcd | none | none |
| Synthrapol[5] | 9.6abc | 19.4 bcde | none | none |
| Triton B-1956[7] | 9.5abc | 18.5 bcde | none | none |
| Ethofat 0.25[1] | 8.9 bc | 14.7 de | none | none |
| Control | 8.4 bc | 32.0abc | — | — |
| Span[2] | 7.7 c | 16.9 bcde | moderate | moderate |
| Buffer X[3] | 5.3 c | 18.0 bcde | none | none |
| Biofilm[3] | 5.1 c | 13.0 e | slight | none |
| Atlox 109[2] | 4.4 c | 12.6 e | none | none |
| Atlox 1045-A[2] | 4.3 c | 14.6 de | none | slight |
| Atplus 300F[2] | 3.1 c | 19.0 cde | none | moderate |
| Examide DA[8] | 3.0 c | 14.5 de | none | none |
| Kessco PEG 100[1] | 2.8 c | 11.6 e | none | none |
| Polyoxyethylene (20) sorbitan monooleate[6] | 2.1 c | 11.2 e | none | moderate |
| Tetronic 908[9] | 2.4 c | 23.8 b d | none | none |
| Hallco CPH-123[4] | 2.0 c | 14.3 de | none | severe |
| Tween 80[3] | 1.6 c | 16.3 cde | none | none |

[z]Means within columns followed by the same letter are not significantly different at $p = 0.05$ by Duncan's Multiple Range Test.

[y]Manufacturers: [1]Armour Ind. Chem. Co., Chicago, IL; [2]Atlas Chem. Ind., Inc., Wilmington, DE; [3]Colloidal Prod. Corp. Sausalito, CA; [4]C.P. Hall, Chicago, IL; [5]ICI Amer. Inc., Stanford, CN; [6]Matheson, Coleman & Bell Co., Norwood, OH; [7]Rohm & Haas, Philadelphia, PA; [8]Soluol Chem. Co., Natich, RI.

**Table 2. Absorption of 25 mM double-labeled $^{86}$Rb $^{33}$P-phosphate, with and without 0.1% AL 825 surfactant, by various herbaceous ornamental woody landscape species.**

| | Percent Absorbed | | | |
|---|---|---|---|---|
| | phosphate | | Rb | |
| **Species** | **alone** | **+ surfactant** | **alone** | **+ surfactant** |
| *Plectranthus australis* | 38.7 | 54.7 | 41.7 | 44.8 |
| *Streptocarpus saxorum* | 13.5 | 9.7 | 35.8 | 14.4 |
| *Pelargonium hortorum* | 11.8 | 10.2 | 44.7 | 24.7 |
| *Pilea cadierei* | 9.8 | 4.3 | 20.7 | 36.5 |
| *Peperomia obtusifolia* | 9.7 | 18.4 | 19.2 | 23.9 |
| *Chrysanthemum morifolium* 'Giant Indianapolis White' | 8.4 | 18.9 | 32.0 | 23.9 |
| *Euphorbia pulcherrima* 'Annette Hegg Supreme' | 4.4 | 3.5 | 26.1 | 4.4 |
| *Coleus hybridus* | 4.3 | 3.9 | 30.1 | 28.8 |
| *Impatiens* 'Carousel' | 3.3 | 21.3 | 6.4 | 13.2 |
| *Pyracantha coccinea* 'Lalandei' | 3.1 | —[z] | 25.0 | —[z] |
| *Saxifraga stolonifera* | 3.0 | —[z] | 2.7 | —[z] |
| *Begonia semperflorens-cultorum* | 2.7 | 6.9 | 4.7 | 7.9 |
| *Ilex crenata* 'Convexa' | 2.7 | —[z] | 27.5 | —[z] |
| *Dianthus caryophyllus* 'CSU White Pike Peak' | 2.5 | 4.9 | 22.1 | 30.4 |
| *Juniperus horizontalis* 'Plumosa' | 1.8 | 34.7 | 0.3 | 19.0 |
| *Taxus media* 'Hicksii' | 0.8 | —[z] | 0.2 | —[z] |
| *Rhododendron* 'Roseum Elegans' | 0.8 | 37.5 | 0.2 | 17.8 |
| *Hydrangea macrophylla* 'Kunhert' | 0.4 | —[z] | 3.8 | —[z] |
| *Pilea microphylla* | 0.2 | 0.6 | 3.5 | 6.9 |
| *Codiaeum variegatum* var. *pictum* | 0.2 | 5.7 | 0.2 | 3.5 |

[z]Not measured.

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


**Melanie A. Turner,[2] David L. Morgan[3] and David Wm. Reed[4]**
*Texas A&M University Research and Extension Center*
*17360 Coit Road, Dallas, TX 75252*



## 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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[2]Present address: W.R. Grace & Co., 100 N. Central Expressway, Suite 614, Richardson, TX 75080.

[3]Associate Professor.

[4]Associate Professor, Department of Horticultural Sciences, Texas A&M University, College Station, TX 77843.