Table 1. Effect of a single foliar spray of BA on number of lateral branches, internode length, and total growth of *Peperomia obtusifolia*.

Treatment (mg/liter)	Mean no. lateral branches[z]	Mean internode length (cm)				Increase in plant ht (cm)
		−1[y]	+1	+2	+3	
0	4.6	3.7	3.3	2.9	2.7	17.1
250	7.4	3.1	2.9	2.0	1.4	13.3
500	9.4	3.4	2.6	1.6	1.1	15.2
1000	10.4	3.3	2.5	1.8	0.8	13.4
		F test significances[x]				
Linear	**	NS	**	**	**	**
Quadratic	**	NS	NS	**	**	NS
Cubic	NS	NS	NS	NS	NS	**

[z]Fourteen replications per treatment.
[y]Position of internodes where (−1) = last node developed at time of treatment; (+1) = 1st node developed after treatment; (+2) = 2nd node and (+3) = 3rd node developed after treatment.
[x]NS,**Nonsignificant and significant at 1% level, respectively.

250, 500, and 1000 mg/liter. BA crystals were dissolved in a few drops of 1N KOH, followed by gradual addition of deionized water coupled with heating and constant stirring. Triton X-100 at 1 drop per liter was used as a wetting agent, and plants were sprayed once to runoff (about 10 ml per plant.) There were 14 plants per treatment arranged in a randomized block experimental design with each plant comprising a single experimental unit. At the time of treatment, plant height was measured from the top of the pot to the tip of the main growing point, and the last fully expanded leaf was marked. Plants were treated 12 Nov. 1983. Final data were taken 12 weeks after treatment. Data consisted of increases in plant height (cm), numbers of lateral breaks and length of the 1st internode below, and the 3 nodes above the leaf marked at the time of treatment. Position of internodes was indicated using the following notation: (−1) = last node developed at time of treatment; (+1) = 1st node developed after treatment; (+2) = 2nd node; and (+3) = 3rd node developed after treatment.

An increase in lateral budbreak in treated plants was noticeable within 4 weeks. After 12 weeks, there was a linear increase in number of lateral buds with increased concentration of BA. Untreated plants averaged 4.6 lateral branches compared to 7.4, 9.4, and 10.4 for the 250, 500 and 1000 mg/liter treatments, respectively (Table 1). The lateral breaks occurred all along the main shoot (Fig. 1). Several lateral branches were accompanied by secondary shoots beginning to emerge from the same leaf axil. No phytotoxicity or deformed growth was observed on treated plants.

The growth of main stems of BA treated plants was reduced significantly during the 1st 12 weeks after treatment (Table 1). Reduced height could be accounted for by a linear decrease in internode length of the 1st 3 internodes developed after the last fully expanded leaf marked at the time of treatment (Table 1). The most pronounced reduction of internode length occurred in the 3rd node, which would have been affected in previous stage of development by the BA application. After 12 weeks, subsequent internodes began to elongate normally, indicating that BA effects were lessening. We have no explanation for the BA effects on internode length of *Peperomia* at this time.

Significant quadratic effects were observed when analyzing number of breaks and internode length of nodes +2 and +3, indicating that response to BA declined as concentration increased. Such results could be depicted by a 2nd degree curve rather than a straight line and indicate that treatment concentration in the range of 250–500 mg/liter BA provide the optimum branching and dwarfing response per unit of active compound. In this study, BA effects resulted in more compact plants with a greater number of lateral branches and therefore may eliminate the need for sticking more than 1 cutting per pot.

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Duplicating Foliage Shade for Research on Plant Development

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Additional index words. phytochrome, shade film, light quality

Abstract. **A shade film is described which duplicates the spectral quality of light underneath foliage. The film should become an important tool for studying plant development, and it may have commercial applications.**

We are beginning to understand the ecological significance of phytochrome for plant development, beyond that of controlling flowering (17). Progress has been frustrated, however, by difficulties in experimental methodology. The quantity and spectral quality of radiation passing through foliage is altered by the optical properties of leaves. Leaves typically absorb 90% of incident light in the wavelengths 400–700 nm and less than 10% of radiation 750–1100 nm (7, 8, 20). Thus, natural light under foliage is deficient in radiation usable for photosynthesis, and is spectrally altered in the wavelengths (650–750 nm) affecting phytochrome equilibria (1, 10, 18). Although shade light may affect plant growth and development profoundly (3, 9, 13, 14, 17), it has been difficult to document its effects because of the heterogeneity of natural light environments (2, 15, 16), and the difficulty of producing artifical ones (17).

Research on the effect of spectral distribution of radiation on plant growth has been hampered by the necessity of including adequate levels of photosynthetic photon flux density (400–700 nm, or PPFD) along with altering the quantum ratios of red to far-red wavelengths [660/730 nm, or R:FR as defined by Smith (17)]. The high R:FR characteristic of sunlight is achieved easily through the use of fluorescent or mercury vapor lamps. However, only moderately low R:FR can be achieved by the use of low wattage tungsten incandescent lamps. This radiation can be altered further by filters (8, 9, 16), but the excess infra-red radiation from the high flux

Received for publication 5 July 1984. Commercial use of the shade film described in this article will be regulated by a pending patent. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

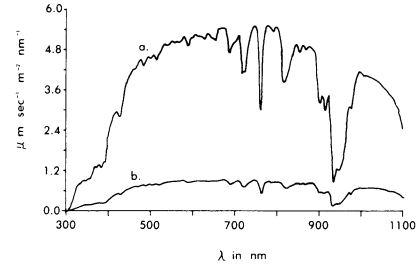

Fig. 1. Spectral distribution of radiation between the wavelengths of 300–1100 nm, in units μmol $s^{-1}m^{-2}nm^{-1}$. **a**. Full sunlight. **b**. Commercial shade house with 83% shadecloth.

densities required to achieve minimal PPFD requires heat filtration and limits the size of the growth chamber. A method for altering sunlight (or an artifical radiation source) to provide levels of PPFD and ratios of R:FR very similar to those under natural shade is described.

To design and construct a film with the necessary optical properties, it was necessary to determine the relationship between shading (percentage of PPFD) and spectral quality (R:FR) in shade films and screens compared to radiation beneath foliage. For this purpose, a LI-COR 1800 spectroradiometer (LI-COR Instruments, Lincoln, NE 68504) with a wavelength response of 300–1100 nm and a half peak bandwidth of 6 nm was employed for all measurements. Spectra were determined at intervals of 2 nm. Quantum integration of each scan at 400–700 nm gave PPFD in μmol s^{-1} m^{-2}. Quantum ratios (658–662/728–732 nm) gave R:FR. Outdoor measurements were performed within 1 hr of solar zenith in full sunlight, in November of 1983. Effects of foliage shade on PPFD and R:FR were measured under isolated trees on the Tamiami Campus of Florida International Univ. and under the closed canopy of a hardwood hammock at Simpson Park in Miami. Radiation conditions under various commercial shade cloths and films were measured at 15 commercial nurseries in southern Dade County in July of 1983. For the preparation and evaluation of the shade film, various pigments and combinations thereof were screened for their similarity in spectral quality to natural shade. The pigments were mixed in a urethane varnish base and sprayed on 22 × 28 cm sheets of cellulose acetate. These sheets were analyzed spectrally under full sunlight by affixing them to a 20 × 26 cm opening on a flat black box 16 cm above the sensor.

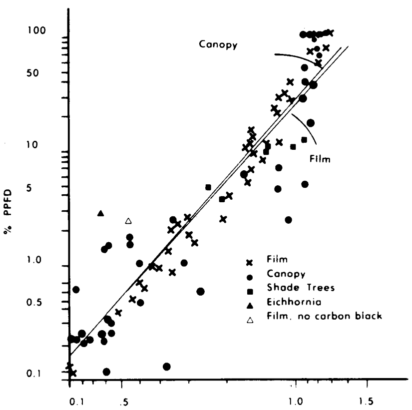

Fig. 2. Relationship between R:FR and percentage of full sunlight underneath individual tree canopies, means of 5 measurements for each variety (■); under a closed forest canopy (●), n = 39; and underneath varying densities of the shade film (x), n = 38. Values indicating the spectral alteration of radiation immediately beneath water hyacinth leaves (*Eichhornia crassipes* Solms.) are indicated by (▲), and values for the film without the addition of carbon black are shown by (△). Points are the means of 5 measurements. Regression lines for hammock and shade film measurements also are given.

Full sunlight measured in this study had a mean R:FR of 1.270 (SD of 0.039, from 24 scans). Commercial shading materials (115 different growth environments analyzed) did not change the spectral distribution of radiation significantly (Fig. 1) and thus had R:FR's identical to full sunlight for all percentages of shading. Shade light underneath foliage was characterized by decreasing R:FR in relationship to decreasing percentages of full sunlight (Fig. 2).

The above results made possible the development of an artificial film that duplicates the properties of natural foliage, from screening many different pigments and combinations. The best shade film is a combination of the following (Fig. 3): 1 part Hostaperm Violet RL pigment; 0.25 parts of Solvaperm Yellow G dye (both obtained from American Hoechst, Inc., Coventry, RI 02816); and 0.40 parts of carbon black pigment. These materials were sprayed routinely on films in a concentration of 10% w/v. These pigments meet 3 important criteria for successful use in constructing outdoor shade environments for studying plant development. First, they are relatively inexpensive. Second, they are stable to both high temperatures and light levels, giving them a long field life and the possibility of incorporation into plastic film (S. Kumar, personal communication). Thirdly, they have the desired spectral characteristics (Fig. 2, 4). Increased pigment density alters R:FR just as the increased shading of thicker foliage does, and extreme shade underneath the artifical film is very similar to that underneath foliage at identical percentages of full sun PPFD. It also is feasable to alter the R:FR of the film for a given percentage of shade by changing the concentration of the spectrally neutral carbon black pigment. For instance, the spectral quality immediately beneath leaves of water hyacinth is altered substantially (Fig. 2), and this shift can be approximated by using the 2 compounds without carbon black.

These pigments, applied as a paint or incorporated in a film, should have wide application in research on plant development in response to light. Long-term studies typically have used different densities of shade cloths or levels of artificial light, neglecting the important spectral shift of radiation in increasing shade under natural conditions (4, 5, 6, 10, 11, 19). Two enclosures, with

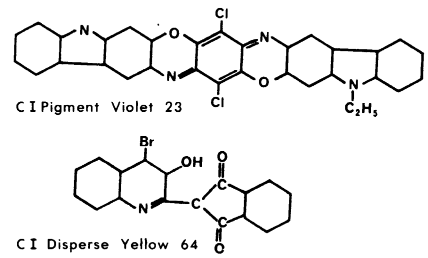

Fig. 3. Structural identification of compounds used for altering spectral distribution of light in the shade film.

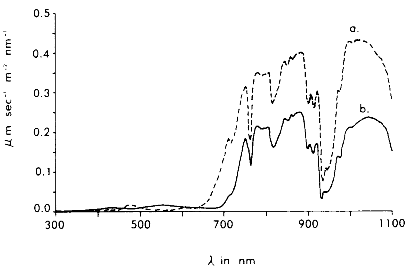

Fig. 4. Spectral distribution of radiation, same units as Fig. 1. **a**. Under a closed forest canopy in Simpson Park. **b**. Underneath the shade film.

identical percentages of shading but with R:FR of full sunlight vs. deep forest shade, now can be constructed to study the effects of spectral quality vs. radiation intensity on long-term developmental responses of plants of small to large stature. The pigments also can be sprayed onto small plastic bags to study the effects of altered spectral quality on a small portion of a plant. The film also could be used to alter the spectral quality of the cool tungsten lamps used in measurements of photosynthesis, producing radiation close to that of natural conditions for measuring the photosynthetic responses of extreme shade plants (12). If the film enhances the growth or quality of foliage plants, or other plants, it may have commercial applications.

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Reducing Corolla Abscission of *Streptocarpus* × *hybridus* under Simulated Shipping Conditions with Silver Thiosulfate

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Additional index words. cape primrose, postharvest quality

Abstract. **Silver thiosulfate (STS) foliar sprays applied 1 and 4 weeks prior to simulated shipping reduced corolla abscission of *Streptocarpus* × *hybridus* Voss. Spray concentrations of 0.5, 1.0, and 2.0 mM were all effective in reducing corolla abscission when appropriately timed. Sprays applied 24 hr prior to shipping caused necrotic lesions on the flowers and foliage and proved harmful in the warm, humid environment used in simulated shipping. A combination treatment with STS (2 mM) sprayed 4 weeks and again 24 hr prior to shipping showed the 4-week spray treatment to precondition the plants thereby preventing injurious effects by the 24 hr treatment and decreasing corolla abscission 46.6%. STS folair sprays applied one week prior to shipping at 0.5 mM and 1.0 mM prevented corolla abscission with 0% corolla abscission after simulated shipping.**

Streptocarpus × *hybridus*, a popular pot crop in Europe, is gaining in popularity in the United States. *Streptocarpus* possesses many qualities necessary for a good pot crop: capability of year-round flowering; a variety of flower colors; long-lasting flowers; attractive foliage; and adaptability to 10 cm pots, 15 cm pots, and hanging baskets (6). It requires minimal care, is an attractive gift suitable for many occasions and, unlike many pot plants, may be maintained and reflowered over several years and with minimal effort by the consumer. Additionally, *Streptocarpus* is adapted to cool temperature regimes (15.5° to 17.0°C nights). This can mean a savings in energy dollars, particularly if the crop is grown for Valentine's, Easter, or Mother's Day sales.

Despite its advantages, *Streptocarpus* abscises a large percentage of opened corollas during shipping, limiting its suitability for production. In attempts to prevent corolla abscission, growers have tried removing opened flowers and shipping in tight bud. This practice, although successful, is labor consuming, and plants in tight bud are not immediately salable.

Flowers evolve ethylene (2, 9), a factor cited as the causative agent in abscission of plant parts (1, 3, 5, 8) and floral senescence (7, 10). Since ethylene is implicated, a logical approach would be the prevention of corolla drop through the use of ethylene inhibitor sprays.

Beyer showed the effectiveness of the silver ion (Ag^+), in the form of silver nitrate ($Ag\ NO_3^+$), to block ethylene action (4). Later, Veen (11) found the anionic complex silver thiosulfate [$Ag(S_2O_3)_2^{\ 3-}$], to be more mobile than $AgNO_3^+$ in plant tissues and to cause less phytotoxicity. Silver thiosulfate (STS) foliar sprays at 2 and 4 mM were effective in preventing flower abscission of *Schlumbergera* when exposed to simulated shipping environments or ethylene (5). The objectives of these experiments were to test the effectiveness of STS foliar sprays in preventing corolla abscission of *Streptocarpus* × *hybridus* and to determine appropriate timing of these sprays.

Expt. 1. Transplants, 5.5 cm of *Streptocarpus* × *hybridus*, an unnamed blue seed variety from Mikkelsen's, Inc., Asthabula, Ohio, were grown in 11.5 cm plastic pots in the Kansas State Univ. greenhouse from 15 Oct. to 19 Dec. 1983 with day/night temperatures of 24°/18°C. When one flower per plant was fully open, plants received the following spray treatments (Trt) applied until runoff: 1) control 0 mM STS spray; 2) 2 mM STS spray applied 4 weeks prior to shipping treatment; 3) STS 2 mM spray applied 24 hr prior to shipping treatment; and 4) 2 mMSTS spray applied 4 weeks and again 24 hr prior to shipping treatment. The 4-week spray treatment was applied on the morning of 19 Dec. 1983, and the 24 hr spray treatment was applied on the morning of 15 Dec. The experiment was repeated twice with the same 4 treatments initiated 2 and 4 days later for consecutive simulated-shipping runs through the growth chamber. The experiment was designed as a split-plot over 3 times. Six replicates of single plant treatments were used in the experiment. The shipping treatment involved sleeving the plants in plastic, packing in ventilated cardboard boxes, and placing in a dark growth chamber at 25° for 48 hr.

After simulated shipping, plants were removed from the sleeves, and the total number of corollas abscised and the total number of open flowers were determined. The percentage of corolla abscission was calculated

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