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Spectral Transmittance of Selected Greenhouse Construction and Nursery Shading Material[1]

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Abstract

Spectral transmittance properties of several greenhouse construction and shading materials were determined by measuring the quantity and quality of solar radiation transmission on non-clouded (sunny) days at solar noon. Spectral transmittance parameters included photosynthetic radiation (400–700 nm) and photomorphogenic radiation (660 nm (red light), 730 nm (far-red light), and 400–500 nm (blue light)). Light available for photosynthesis was measured as photosynthetic photon flux density (PPFD) and photosynthetic radiation (PI). Photomorphogenic radiation was measured as far-red/red (FR/R) and blue light. Greenhouse construction materials included glass, chambered acrylic, chambered polycarbonate, and inflated plastic film. Various shade materials of different colors were evaluated. Photosynthetically active radiation transmission of construction materials ranged from approximately 95% transmission of direct sunlight with Exolite to less than 50% with tinted Lexan. Far-red/red values of shade materials ranged from 0.94 for Enduro Green to 5.58 for Cravo LS-7.

Index words: Far-red:red ratio, photomorphogenesis, light quality, photosynthetic photon flux density, photosynthetic irradiance, phytochrome, blue-light

Significance in the Nursery Industry

The quantity of photosynthetic energy reaching a plant affects plant growth. Light levels can influence photosynthetic rates, but plant growth and form may also be affected.

Transmitted light quantity and quality varies among greenhouse construction and shading materials. Visual appearance of the materials is deceiving (e.g., similarly appearing green shading materials had vastly different spectral properties). These transmission differences may have very different effects on plant growth and development and may influence production practices. Although we did not measure plant growth under the different materials in this study, other research that we have conducted indicates a high far-red/red (FR/R) environment may be more suitable than one with a low FR/R transmittance when short, compact plants are desired while. Likewise, taller plants may be the result of a high FR/R environment. Growers need to be aware of the spectral filtering characteristics of construction and shading materials. Transmission specifications must be considered before installation or application of a material under which plants will be grown.

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Introduction

Greenhouse construction and nursery shading products reduce the solar radiation reaching plants grown under these materials. This reduction is often desirable and planned, especially in the summer when irradiance levels are high. Reducing solar radiation assists in cooling the greenhouse and protects plants from excessive heat and light. In general, the main concern in reducing light has been reduction of overall intensity of irradiance level. Little or no attention, however, has been directed at the effect construction and shading materials have on the alteration of spectral light quality.

Photosynthesis is active at wavelengths between 400 and 700 nm (7). In contrast, phytochrome activity and photomorphogenic development of plants is controlled by far-red/red light ratio (730 nm/660 nm) (1, 2, 3) and the amount of blue light (400–500 nm) (4, 6). Selectively altering light wavelengths can influence plant growth and morphology (1, 3, 5). Many plants grown under low far-red/red ratios are more compact and darker green than plants grown under high ratios (5). Exposure of plants to short-term end-of-day red or far-red light can induce profound changes in plant morphology (2). The objective of this study was to document different light filtering characteristics of some greenhouse construction and nursery shading materials.

Materials and Methods

Several commercial greenhouse construction and shading materials were evaluated for their light transmittance properties of wavelengths between 400 and 850 nm. Measurements were taken with a LI-COR LI-1800 spectroradiometer equipped with a LI-1800-10 remote cosine sensor (LI-COR, Lincoln, Nebraska). Readings were taken at approximately solar noon (sun at its zenith) on representative cloudless days during the spring of 1989.

A piece of plywood, approximately 25 × 25 cm (7 × 7 in) was placed behind the sensor and a wooden frame approximately 12 × 14 × 5 cm (3.4 × 4.0 × 1.4 in) was placed around the sensor. Both the backing and the frame were painted flat black. The material to be evaluated was placed horizontally across the frame. In cases where the material was smaller than the frame opening, the uncovered area was masked with a piece of opaque black plastic. The frame and sensor were positioned to face directly into the sun as determined by shadow pattern. All materials tested were clean and new. Plastic films were doubled, sealed along the edges, and inflated with air. The latex paint and green shading compound were diluted with water (1:4 and 1:14, respectively). Liquid shading materials were uniformly sprayed one time to just before run-off on a piece of clean glass tilted to approximate the slope of a greenhouse roof.

Full sun measurements were taken every 30 min. to record solar spectral differences resulting from atmospheric changes and/or sun movement. Measurements were made in 2 or 5 nm increments. The frequency of solar readings allowed no more than 15 min. between measurements of material transmittance and comparative solar readings. Two readings were taken for each material to insure that the measurements were accurate. One reading was chosen as representative since total transmission varied only 3% or less between any of the pairs of readings.

Measurements were expressed as percent of direct sun and included photosynthetic photon flux density (PPFD) in $\mu mol \cdot m^{-2} \cdot s^{-1}$ from 400 to 700 nm; photosynthetic irradiance (PI) in $W \cdot m^{-2}$ from 400 to 700 nm; blue light from 400 to 500 nm in $W \cdot m^{-2}$; and ratio of far-red (728–732 nm for 2 nm increments and 725–730 for 5 nm increments) to red light (658–662 for 2 nm increments or 655–660 for 5 nm increments).

Results and Discussion

Construction materials had PPFD transmission ranging from 95% through glass to 44% through tinted Lexan (Table 1). Blue light and PPFD were not transmitted at the same percentage for many materials. Blue light transmission was 10% less than PPFD through Fog-bloc yellow double polyethylene films while blue light and PPFD transmission through glass was equal. Far-red/red ratio ranged from 0.97 for glass to 1.05 for Fog-bloc yellow.

Shade materials varied greatly in transmission properties (Table 2). Far-red/red ratio ranged from 0.94 for Enduro Green to 5.58 for Cravo LS-7. The PPFD ranged from 49% transmission for V-J Weathershade to 21% for Enduro Silver and Cravo LS-7. The PPFD reduction was within 5% of the manufacturer's listed specifications for all fabrics.

Cravo LS-7 transmitted 6% more blue light than PPFD while Kool Ray green shading compound transmitted 35% PPFD compared to 7% transmission for blue light. The percent transmission of all light through the shading compound would depend on number of applications and dilutions of the compound, however, the spectral altering characteristics would be unaffected by application density. In this study, liquid shading compounds were applied uni-

Table 1. Spectral transmission properties of selected greenhouse coverings.

	Photosynthetic Light		Photomorphogenic Light	
Material	Photosynthetic Photon Flux Density (PPFD) 400–700 nm ($\mu mol \cdot m^{-2} \cdot s^{-1}$) *Expressed as % full sun*	Photosynthetic Irradiance (PI) 400–700 nm ($W \cdot m^{-2}$) *Expressed as % full sun*	Blue Light 400–500 nm ($\mu mol \cdot m^{-2} \cdot s^{-1}$) *Expressed as % full sun*	Far-red/Red 730/660 nm ($W \cdot m^{-2}$) Ratio *Compared to full sun*
	%	%	%	
Glass	93	93	93	0.97
Monsanto 602[z]	88	88	83	1.01
Monsanto 703[z]	67	67	63	1.04
Monsanto Cloud-9[z]	52	52	48	1.04
Fog-bloc 6 mil[y]	68	68	64	0.98
Fog-bloc 6 mil[x]	63	62	53	1.05
Exolite[w]	95	95	92	1.02
Lexan[v]	78	77	75	1.04
Lexan[u]	44	44	38	1.04

[z]Greenhouse film (doubled and inflated) (Monsanto, Inc., St. Louis, MO).

[y]Clear polyethylene (doubled and inflated) (FVG-America, Inc., Minneapolis, MN)

[x]Yellow polyethylene (doubled and inflated) (FVG-America, Inc., Minneapolis, MN).

[w]Chambered acrylic (Cyro Industries, Mt. Arlington, NJ).

[v]Chambered polycarbonate (General Electric Co., Cleveland, OH).

[u]Chambered polycarbonate (tinted) (General Electric Co., Cleveland, OH).

Table 2. **Spectral transmission properties of selected nursery and greenhouse shading materials.**

Material	Photosynthetic Light: Photosynthetic Photon Flux Density (PPFD) (μmol·m^{-2}·s^{-1}) *Expressed as % full sun*	Photosynthetic Light: Photosynthetic Irradiance (PI) 400–700 nm (W·m^{-2}) *Expressed as % full sun*	Photomorphogenic Light: Blue Light 400–500 nm (μmol·m^{-2}·s^{-1}) *Expressed as % full sun*	Photomorphogenic Light: Far-red/Red 730/660 nm (W·m^{-2}) Ratio *Compared to full sun*
	%	%	%	
Kool Ray[z]	35	35	7	1.83
Paint[y]	41	41	39	0.99
Chicopee[x]	45	45	44	1.00
V-J Weathershade[w]	49	49	49	0.99
Enduro Silver[v]	21	21	18	1.06
Enduro Green[u]	42	41	40	0.94
Chicopee Lumite[t]	35	34	34	1.04
Cravo LS-7[s]	21	22	27	5.58

[z]Kool Ray green (Continental Products Co., Euclid, OH).

[y]White latex paint.

[x]Black, woven fabric (55% shade) (Chicopee, Inc., Gainesville, GA).

[w]Black, knitted fabric (50% shade) (V-J Weathershade, Apopka, FL).

[v]Vinyl coated polyester fabric with aluminum pigment (80% shade) (Handlee Enterprises, Houston, TX).

[u]Vinyl coated polyester fabric (80% shade) (Hendlee Enterprises, Houston, TX).

[t]Green, woven saran fabric (63% shade) (Chicopee, Inc., Gainesville, GA).

[s]Green polyester fabric (Cravo, Ltd., Bramford, Ontario, Canada).

formly one time to just before run-off and were allowed to dry before measurements were taken.

Light filtering by greenhouse construction and shade materials segregated into two broad categories, non-selective and selective. Non-selective filters characteristically transmit all wavelengths uniformly (Figure 1) while selective filters transmit wavelengths disproportionately (Figure 2). Many of the neutral colored shade materials (black, white, and silver) tested were non-selective filters, while the construction materials and green shade materials were selective filters with varying light transmittance properties.

Alterations in the natural far-red/red ratio by shading materials Enduro Green (0.94), Chicopee Lumite saran (1.04), Kool Ray green shading compound (1.83), and Cravo LS-7 (5.58) suggests that light filtering properties of these materials could affect plant growth. Plants exposed to high far-red/red ratios have been reported to have increased internode lengths and leaf areas (2, 3). Often, increases in plant height ("stretching") are attributed to reduced light in shaded greenhouses or nursery areas, but the quality of light reaching the plant may also contribute to increases in plant height by elongating internodes.

The percent of blue light transmitted by some materials was not the same as percent PPFD transmittance. Fog-bloc (yellow) polyethylene reduced blue light 10% more than PPFD, indicating that blue light was filtered more than red

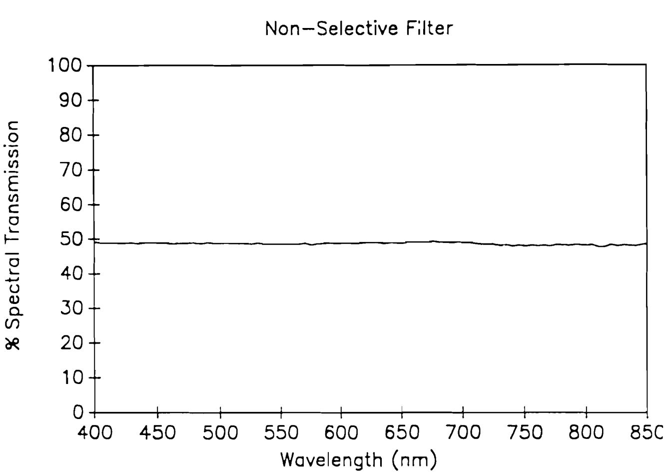

Fig. 1. Example of a non-selective filter using spectral transmission values for V-J Weathershade 50% knitted black shade cloth.

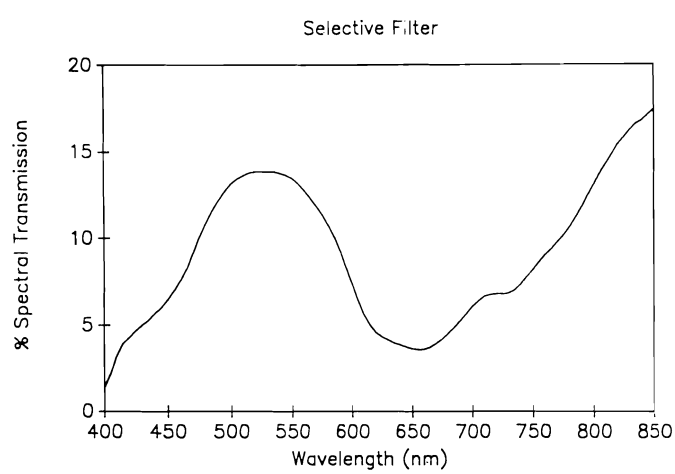

Fig. 2. Example of a selective filter using spectral transmission values for Kool Ray green shading compound.

light. In other materials such as glass, other films, and rigid plastics, the difference was 0–6%. Cravo-LS-7 allowed a 6% higher transmittance of blue light than PPFD, indicating that red light transmittance was reduced more than blue (Tables 1, 2). The blue light filtering characteristics of some materials could alter photosynthetic and photomorphogenic activity (8).

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Propagation of *Heptacodium jasminoides* Airy-Shaw by Softwood and Semi-hardwood Cuttings[1]

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Abstract

Softwood and semi-hardwood two node cuttings of *Heptacodium jasminoides* from basal and middle stem sections rooted better than terminal sections. Basal and middle softwood cuttings exhibited greater rooting (65 and 55% resp.) than terminal cuttings (42%). Basal softwood cuttings produced more roots (7.0) than terminal cuttings (3.8). Root length and rootball diameter were not different among the three cutting positions. Semi-hardwood basal cuttings produced an average of 53.5 roots, while middle and terminal cuttings produced 25.8 and 19.7, resp. Cuttings treated with the potassium salt formulation of indolebutyric acid (K-IBA) exhibited increased rooting, greater root number and length, and greater rootball diameter in softwood cuttings. Semi-hardwood cuttings treated with K-IBA rooted in higher percentages and produced more roots than untreated cuttings.

Index words: rooting, auxin, node position

Significance to the Nursery Industry

Nurserymen who want to propagate *Heptacodium*, a small deciduous flowering tree, would be most successful by using basal and mid-section cuttings. Cuttings treated with a 5000 ppm K-IBA 10 second quick dip should root readily within 12 weeks. Two node cuttings were used in this study to maximize plant material resources, however similar results would be expected with larger multi-node cuttings.

Introduction

Heptacodium jasminoides is a small deciduous flowering tree native to Western Hupeh, China (1). It is considered a rare plant even in its native habitat and was only available to the western world following the 1980 Sino-American Botanical Expedition to China (2). *Heptacodium jasminoides* has potential as a new nursery crop because of its exfoliating bark, vigorous growth and fragrant white late summer flowers. After flowering, the persistent calyces develop an attractive reddish color in the fall.

To introduce and promote a new plant to the nursery industry a defined propagation procedure for multiplication and distribution to nurserymen is required. Propagation of *Heptacodium jasminoides* by seed has not been studied extensively, however in preliminary studies, germination of seed has been slow and in low percentages (1). Propagation of dormant hardwood cuttings by the authors produced no rooted cuttings. Successful propagation by softwood cuttings using 10,000 ppm indolebutyric acid (IBA) in a mixture of ethyl alcohol and deionized water (1:1 by vol) has been reported (2). Preliminary studies in 1987 by the authors compared single node softwood cuttings taken from the terminal, middle and basal sections of stems. The basal portion of each cutting was immersed in a 50% ethanol solution containing one of three IBA treatments: 0, 2500, or 10,000 ppm indolebutyric acid (IBA). Results indicated basal sections rooted better than middle or terminal sections.

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