Growth Regulation of Sub-Tropical Perennials by Photoselective Plastic Films[1]

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Abstract

Plant response to photoselective plastic films with varying spectral distribution properties was tested using three sub-tropical perennials: golden shrimp plant (*Pachystachys lutea*), Persian shield (*Strobilanthes dyerianus*), and cat whiskers (*Orthosiphon stamineus*). Films were designated YXE-10 [far-red (FR) light-absorbing film] and SXE-4 [red (R) light absorbing film]. Light transmitted through YXE-10 films reduced plant height (stem length) of golden shrimp plant and cat whiskers by 10 and 20%, respectively. Light transmitted through SXE-4 films increased plant height by 9% for golden shrimp plant but did not significantly increase stem length of Persian shield and cat whiskers species. Chlorophyll, leaf area, and mean days to flower generally were not affected by photoselective films, with the exception that cat whisker plants grown under YXE-10 films had reduced leaf area when compared to plants grown under SXE-4 or control films. As compared to the control film, light transmitted through YXE-10 films reduced leaf dry weight by 22–31% and stem dry weight by 19–28%, depending on the plant species. Root dry weight was not affected by spectral films.

Index words: spectral filters, greenhouse covers, photomorphogenesis, height control, light quality, far-red light.

Species used in this study: golden shrimp plant (*Pachystachys lutea* Nees.), Persian shield (*Strobilanthes dyerianus* M.T. Mast.), cat whiskers (*Orthosiphon stamineus*).

Significance to the Nursery Industry

Photoselective greenhouse films offer a non-chemical alternative to regulate plant growth. Commercial availability and utilization of photoselective films can potentially reduce costs for growth regulating chemicals, reduce employee health risks, and reduce chemical exposure to non-target ecosystems. Although photoselective films effectively alter plant growth, concerns exist relating to their spectral stability, reduction of light transmission, and variable effects across many species. In this study, experimental films that absorb red (R) wavelengths (stimulate elongation) or far-red (FR) wavelengths (reduce elongation) were used to regulate height of several sub-tropical perennial species including golden shrimp plant, Persian shield, and cat whiskers. Far-red light absorbing films produced compact plants with as high as a 20% height reduction (cat whiskers). Red light absorbing films increased height of golden shrimp plant by 9% but did not significantly increase plant height of Persian shield or cat whiskers. These results indicate that photoselective greenhouse films can effectively regulate plant growth of several perennial species.

Introduction

Chemical growth regulators are commonly used in the horticulture industry to reduce plant height, obtain more consistent plant size, and facilitate shipping (6). However, due to perceived risks to humans and the environment, the use of some chemical growth regulators has been severely restricted for landscape and foliage plant use and completely banned for use on food crops. Restricted use of growth regulating chemicals on landscape and foliage crops has increased the need for non-chemical alternatives to regulate growth of greenhouse crops. As an alternative to using chemicals, light quality in the greenhouse can be manipulated by using photoselective greenhouse covers to control height of greenhouse crops non-chemically. Mitsui Chemicals, Inc. of Japan has produced experimental photoselective films using pigments that absorb red (R) or far-red (FR) wavelengths from the natural spectrum. Red light-intercepting films were designed to lower R:FR ratios (elongation stimulating-tall type), and FR light absorbing films were designed to increase R:FR ratios (elongation reducing-dwarf type). Longer stems produced under R light absorbing films may prove beneficial to the cut flower industry while shorter stems produced under FR light absorbing films may be advantageous to the bedding plant industry.

Red and FR light-absorbing photoselective films have been shown to manipulate growth in a variety of vegetable and ornamental plant species (8). The response depends on the species and the cultivar (8). The potential commercial applications of photoselective films have driven several international plastic manufacturers to develop plastics with various spectral properties (5, 7, 10). However, the effects of photoselective films on sub-tropical, perennial plants grown in Central-South Florida (USDA hardiness zone 9b, AHS heat zone 9) have not been investigated. The objective of this work was to determine the effects of photoselective greenhouse films on plant growth of three sub-tropical perennials: golden shrimp plant (*Pachystachys lutea* Nees.), Persian shield (*Strobilanthes dyerianus* M.T. Mast.), and cat whiskers (*Orthosiphon stamineus*).

Materials and Methods

Uniform plugs of golden shrimp plant, persian shield, and cat whiskers (approximately 5, 7, and 13 cm (2.0, 2.8, and 5.1 in) tall, respectively) (Robrick Nursery, Hawthorne, FL) were planted into 3.8 liter (1 gal) pots filled with a soilless medium (Fafard Mix #2, Fafard, Inc., Apopka, FL). Plants were transferred to chambers (90 × 60 × 104 cm) (36 × 24 ×

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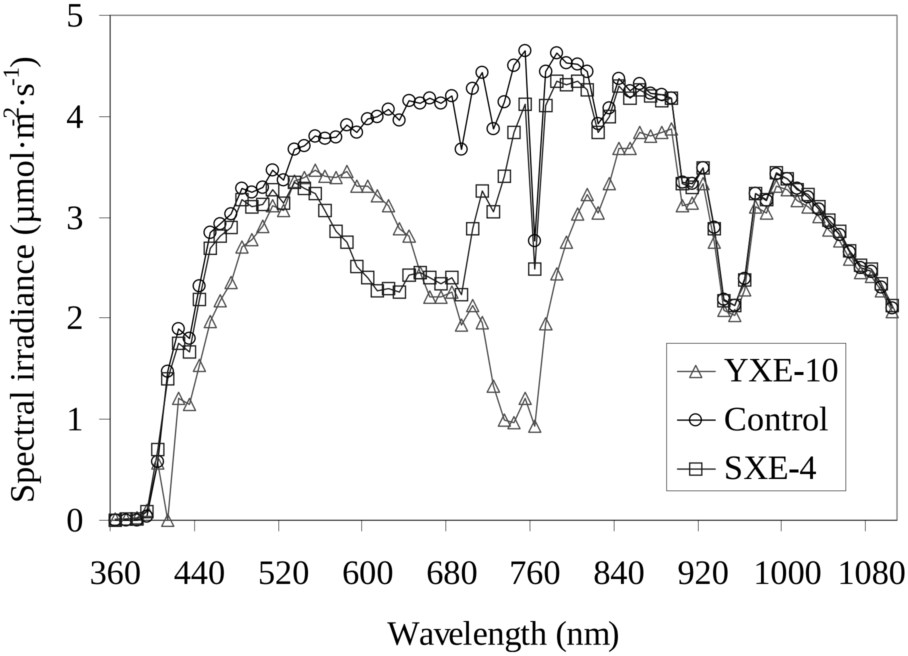

Fig. 1. Spectral transmission properties of YXE-10 (far-red light absorbing) and SXE-4 (red light absorbing) photoselective films. Control film is a polyethylene film without dye.

41 in) framed with PVC pipe and covered with experimental, photoselective, polyethylene films. Films were identified by code names YXE-10 (FR light-absorbing film), SXE-4 (R light-absorbing film), and control (clear film). Two fans were placed in opposite sides of each chamber to ensure proper airflow and prevent heat build-up. Spectral distribution of light transmitted through films was measured at the beginning and end of the experiment (Fig. 1) using a LI-1800 Spectroradiometer (Li-COR Inc., Lincoln, NE) and it was confirmed that the spectral integrity of the films was unaltered during the experiment. The R:FR ratio of transmitted light was calculated as the photon flux ratio between 600 and 700 nm (R) and 700 and 800 nm (FR) (Table 1). Phytochrome photoequilibrium was calculated (9) using the spectroradiometer data between 350 and 850 nm (Table 1). The photosynthetic photon flux (PPF) inside each chamber was measured mid-day at bench level with a LI-COR quantum meter and adjusted to 515 ± 68 $\mu mol \cdot m^{-2} \cdot s^{-1}$ using cheesecloth placed on top of the chambers. All plants were fertilized (top-dressed) at a standard rate of 15 g/pot (0.53 oz) of 15N–3.9P–10K (15–9–12, Osmocote Plus® (The Scotts Co., Marysville, OH) and treated with a 1% granular systemic insecticide, Imidacloprid (Marathon™) at a standard rate of 0.37 g/liter (0.02 oz/gal) (Olympic Horticultural Products, Bradenton, FL). Plants were inspected daily and hand watered as needed. Temperatures inside and outside of experimental chambers were recorded continually with a Ryan Universal K temperature recorder (Ryan Instruments, Redmond, WA). Average minimum and maximum temperatures in the greenhouse were 24 and 35C (75 and 95F) for trial 1 and 22 and 35C (72 and 95F) for trial 2. Average minimum and maximum temperatures inside the chambers were 24 and 37C (75 and 99F) for trial 1 and 21 and 33C (70 and 91F) for trial 2. Plant height (height from potting medium surface to apex of central stem), number of fully expanded leaves, total leaf area, leaf greenness, and dry weight of leaves, stems, roots, and flowers were recorded after 6 weeks. For Persian shield, plant height was recorded by averaging the stem length of the two primary branches. Average internode length (plant height divided by number of leaves on two main stems) was measured at 0, 2, 4, and 6 weeks (data shown for 6 weeks only). For dry weight measurements, tissue was oven-dried at 49C (120F) for 1 week. Flowering time was recorded when the first white flower protruded from the yellow bract (golden shrimp plant), and when the first purple flower opened (cat whiskers). Average leaf greenness was measured from leaves on the 4th, 5th, and 6th node from the apex of each plant using a Spad-502 meter (Spectrum Technologies Inc., Plainfield, IL). Due to the dark purple foliage, lack of flowers, and fibrous root system of Persian shield, leaf greenness, mean days to flower, and root dry weight were not determined for this species.

Table 1. R:FR ratios and estimated photoequilibrium (Pfr/P) of light transmitted through YXE-10 (far-red light absorbing) and SXE-4 (red light absorbing) photoselective films. Control film is a polyethylene film without dye.

Treatment	R:FR[z]	Photoequilibrium (Pfr/P)[y]
YXE-10	1.51	0.77
SXE-4	0.65	0.66
Control	0.96	0.70

[z]R = 600–700 nm red light; FR = 700–800 nm far-red light

[y]Estimated as described by Sager et al. (9)

Due to space limitations, the experiment was conducted using golden shrimp plant and Persian shield in trial 1 and cat whiskers in trial 2. Experimental chambers were randomly placed in the greenhouse. Treatments were replicated twice with four plants (golden shrimp plant), five plants (Persian shield), or six plants (cat whiskers) randomly placed in each replicate. Data were analyzed using analysis of variance procedure and differences among treatment means were tested by Duncan's multiple range test at $P = 0.05$.

Results and Discussion

Golden shrimp plant. Light transmitted through YXE-10 films reduced plant height by 10.2% but did not affect chlorophyll, total leaf area or flowering time as compared to the control treatment (Fig. 2, Table 2). This correlated with decreased dry matter accumulation in leaf and stem tissue of plants grown under the YXE-10 film and a low shoot:root ratio (Table 3). The low shoot:root ratio suggests that less photosynthates were used for developing shoots than roots when plants were grown under film with a high R:FR ratio (1.51). Similarly, other researchers have shown that FR light-absorbing photoselective films reduced height of chrysanthemum (*Dendranthema* x *grandiflorum* Ramat.) and bell pepper (*Capsicum annuum* L.) (3). Light transmitted through SXE-4 films increased plant height but did not affect chlorophyll, leaf area, flowering time, or dry weight as compared to the control treatment (Tables 2 and 3). Previously, R light-absorbing photoselective films (low R:FR ratios) were shown to increase plant height in other ornamentals such as snapdragon (*Antirrhinum* L.) and petunia (*Petunia* Vilm.-Andr.) as well as a variety of vegetables (8). Similarly, Murakami et al. (5) showed, 10 days after planting, the stem length of sunflowers (*Helianthus annuus* L.) had decreased by 39% in the FR-intercepting treatment and increased by 21% in the R-intercepting treatment compared with the control treatment. Growth responses of golden shrimp plant to spectral films were detected as early as 4 weeks and were more pronounced at 6 weeks (Data not presented).

Persian shield. Light transmitted through YXE-10 films did not significantly affect plant height, average internode length, or total leaf area of plants when compared to the control film (Table 2, Fig. 2). However, plants grown under YXE-10 films had lower leaf and stem dry weights when compared to plants grown under SXE-4 or control films (Table 3). This indicates that the YXE-10 treatment affected dry matter partitioning into leaves and stems. This is consistent with research by Cerny et al. (1) who showed that shoot dry weight of bell peppers decreased when grown under FR absorbing films with a similar R:FR ratio. Likewise, Li et al. (3) showed that as the R:FR ratio of photoselective films increased, the percentage dry matter accumulation in chrysanthemums decreased in stems from 34 to 24%.

Light transmitted through SXE-4 films increased average internode length by 16.4% but did not significantly affect plant height, total leaf area, and leaf or stem dry weight when compared to the control film (Tables 2 and 3). Differences in stem length of plants grown under SXE-4 or YXE-10 films increased as time in the spectral chambers increased from 2 to 6 weeks (Data not presented).

Cat whiskers. Light transmitted through YXE-10 films reduced plant height, average internode length, and total leaf area but did not significantly affect chlorophyll or mean days to flower (Table 2, Fig. 2). The reduction in plant height was apparent as early as 2 weeks after plants were placed in spectral chambers (Data not presented). McMahon (4) showed that normal production techniques for chrysanthemum may be used in conjunction with FR-absorbing filters without affecting flowering time. Khattak et al. (2) reported that a R-absorbing spectral filter developed by van Haeringen et al. (10) delayed flowering time of chrysanthemum by only 2 days. Khattak et al. (2) also reported that plants treated with low N levels (0.316 mM) (19.16 ppm KNO_3) and low photoequilibrium (Pfr/P = 0.62) developed the larger leaf area while those grown under high photoequilibrium (Pfr/P = 0.77) developed a smaller leaf area.

YXE-10 treated cat whisker plants had 31% and 28% lower leaf and stem dry weight, respectively, as compared to plants grown under control films (Table 3). Similarly, Oyaert et al. (7) reported a decreased dry weight in stem and leaf tissue

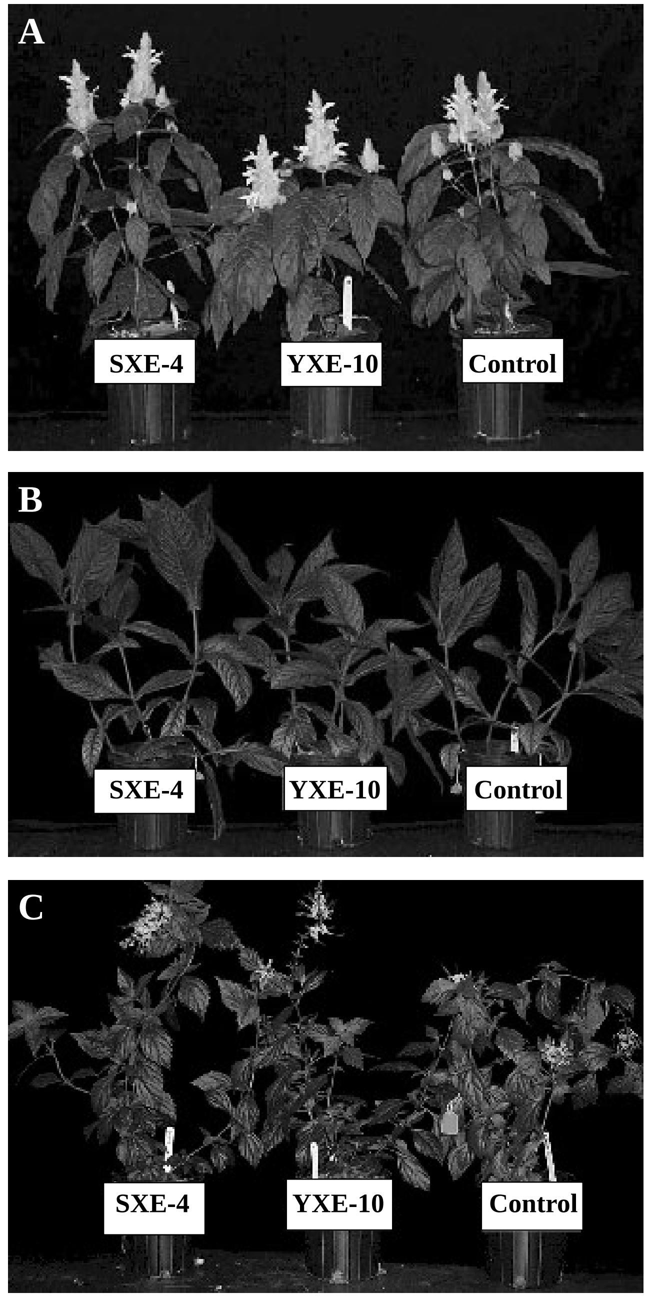

Fig. 2. Effects of YXE-10 (far-red light absorbing) and SXE-4 (red light absorbing) photoselective films on plant growth and appearance of golden shrimp plant (A), Persian shield (B), and cat whiskers (C) at 6 weeks.

Table 2. **Growth characteristics of golden shrimp plant, persian shield, and cat whiskers grown for 6 weeks under greenhouse photoselective films with varying R:FR ratios.**

Treatment[z]	Leaf greenness (Spad units)	Plant height (cm)	Avg internode length (cm)	Total leaf area (cm^2)	Days to flower
	golden shrimp plant				
YXE-10	58.21a	27.00c[y]	3.93a	1980a	37.63a
SXE-4	60.65a	32.78a	4.31a	2265a	38.00a
Control	59.54a	30.08b	4.34a	2195a	38.13a
Significance	NS	.0040	NS	NS	NS
	Persian shield				
YXE-10	—	30.21b	3.24b	2303a	—
SXE-4	—	38.90a	3.97a	2718a	—
Control	—	34.17ab	3.41b	2971a	—
Significance	—	.0093	.0065	NS	—
	cat whiskers				
YXE-10	50.667a	46.814b	2.928b	1495b	34.3ab
SXE-4	49.492a	58.869a	3.413a	1757a	31.0b
Control	49.583a	58.653a	3.269a	1908a	36.5a
Significance	NS	.0001	.0165	.0089	.0750

[z] XE-10 = far-red light absorbing film, SXE-4 = red light absorbing film.

[y]Means followed by different letter are significantly different.

when chrysanthemum plants were grown under polyethylene spectral filters with different pigment concentrations and a translocation of carbon from stems to leaf tissue. The root dry weight and shoot:root ratio of plants grown under YXE-10 were lower but not significantly different from other treatments. There was no significant difference between plants grown under control films or SXE-4 films, with the exception that plants grown under SXE-4 films had lower leaf dry weight than plants grown under control films and flowered in fewer days.

The results indicate that plant height can be manipulated by selective reduction of red or far-red wavelengths from sunlight. However, the magnitude of height control varied with each species. Golden shrimp and cat whiskers produced under far-red light absorbing film (YXE-10) were shorter than the control plants while plants produced under red light absorbing film (SXE-4) had similar (Persian shield and cat whiskers) or increased (golden shrimp plant) height compared to the control plants. Further investigations are underway to identify the species that are responsive to light manipulation and develop industry guidelines to take advantage of new technology.

Table 3. **Dry weight (DW) measurements of golden shrimp plant, persian shield, and cat whiskers grown for 6 weeks under greenhouse photoselective films with varying R:FR ratios.**

Treatment[z]	DW leaves (g)	DW stem (g)	DW root (g)	Shoot:root ratio
	golden shrimp plant			
YXE-10	5.76b[y]	2.50b	1.65	5.01b
SXE-4	6.76a	3.09a	1.55	6.37a
Control	7.05a	3.09a	1.39	7.32a
Significance	.0137	.0162	ns	.0119
	Persian shield			
YXE-10	6.63b	3.14b	—	—
SXE-4	8.46a	4.34a	—	—
Control	8.49a	4.23a	—	—
Significance	.0484	.0483	—	—
	cat whiskers			
YXE-10	3.82c	2.77b	1.21	5.512
SXE-4	4.86b	3.82a	1.31	6.518
Control	5.54a	3.83a	1.50	6.573
Significance	.0001	.0001	ns	ns

[z]YXE-10 = far-red light absorbing film, SXE-4 = red light absorbing film.

[y]Means followed by different letter are significantly different.

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