J. Appl. Hort., 3(2):71-74, July-December, 2001

Use of photoselective plastic films to control growth of three perennial salvias

S.B. Wilson[a] and N.C. Rajapakse[b]

[a] Indian River Research and Education Center, Institute of Food and Agricultural Sciences, University of Florida, 2199 South Rock Road, Fort Pierce, FL 34945, USA, E-mail: sbwilson@mail.ifas.ufl.edu. [b]Department of Horticulture, E142 Poole Agriculture Building, Clemson University, Clemson, SC 29634, USA, E-mail: nrjpks@clemson.edu

Abstract

Photoselective greenhouse films offer a non-chemical alternative to regulate plant growth. Plant response to a photoselective plastic film with a red (R) or far-red (FR) absorbing property was tested using the three perennial salvias: Indigo Spires sage (*Salvia* x 'Indigo Spires') (*Salvia longispicata* Martius Galeotti x *Salvia farinacea* Benth.), Wine sage (*Salvia splendens* 'Van Houttei' Sell x roenen Schultes), and Mexican sage (*Salvia leucantha* Cav.). Films were designated A_{FR} (FR light-absorbing film), A_R (R light-absorbing film) and control (clear plastic film). Solar light transmitted through the A_{FR} film reduced plant height by 17-36%, depending on the species. This correlated with a reduction in internode length and stem dry weight. Light transmitted through the A_R film did not significantly affect plant height, regardless of species. Leaf area was not significantly affected by the A_{FR} or A_R film as compared to the control film, regardless of species. Leaf dry weight of plants grown under A_{FR} was reduced for indigo spires sage and Mexican sage but insignificant for wine sage. Flower development (days to flower and flower number) was not significantly affected by the A_{FR} or A_R film as compared to the control film, with the exception that flower number of indigo spires sage was reduced when grown under A_{FR} film. These results indicate that compactness of three perennial sages can be achieved by selective reduction of far-red wavelengths from sunlight.

Key words: Spectral filters, greenhouse covers, photomorphogenesis, height control, light quality, far-red light, *Salvia leucantha*, *Salvia splendens* 'Van Houttei', *Salvia* 'Indigo Spires', Mexican sage, wine sage, indigo spires sage.

Introduction

The involvement of far-red (FR) light (700-800 nm) in stem elongation of plants is well established (Smith, 1994). Plants grown under a tree canopy or under close spacing conditions often have a spindly appearance because of the relative increase in FR light. Under commercial nursery conditions, it is necessary to place plants close together to maximize space utilization and profits. Therefore, spindly plants are a common problem in commercial nursery production and the use of chemical growth retardants is a standard practice to control stem elongation.

By removing the FR light from the production environment, plant height can be controlled with no (or reduced) chemical applications. Plastic greenhouse covering or shading material with the ability to filter out FR light offers a commercially feasible means of removing FR light from the growing environment. Several plastic and pigment manufacturers in Europe and Japan are working together to develop such photoselective material (Murakami *et al.*, 1997; van Haeringen *et al.,* 1998). Other films have been designed to absorb R (600-700 nm) light wavelengths and decrease R:FR ratios of the light spectrum, thereby producing taller plants. Preliminary tests, which focused on herbaceous horticultural crops, showed that effective height control could be achieved without chemical growth regulators (Rajapakse *et al.*, 1999). However, the magnitude of the response depends on the species and cultivar. For commercial viability of photoselective films, it is important that a wide range of crops respond to light manipulation because today's grower produce diverse crops in their production facilities.

One of the limitations of photoselective films is that they reduce the transmission of photosynthetic photon flux (PPF). The current spectral films reduce PPF by about 25%, and may therefore be more suited for southern latitudes where the irradiance is higher. The objective of this work was to evaluate the effect of FR (A_{FR}) and R (A_R) light absorbing photoselective greenhouse films on plant growth of the three perennial salvia species in Southern latitudes. Perennial salvia was chosen for this study due to its increasing popularity among consumers (Sutton and Picton, 1999; Clebsch, 2001) and its characteristic tall, lanky growth (up to 4 feet), which often makes it difficult to handle and ship without growth retardants (Burnett *et al.*, 2000).

Materials and methods

Plant material and photoselective chambers: Uniform plugs of indigo spires sage (*Salvia* x 'Indigo Spires') (7.8 cm tall) (Robrick Nursery, Hawthorne, FL), wine sage (*Salvia splendens* 'Van Houttei') (9.6 cm tall) (Robrick Nursery, Hawthorne, FL), and Mexican sage (*Salvia leucantha*) (7.4 cm tall) (Hatchett Creek Farms, Gainesville, FL) were planted into 3.8 L pots filled with soilless media (Fafard Mix #2, Fafard, Inc., Apopka, FL).

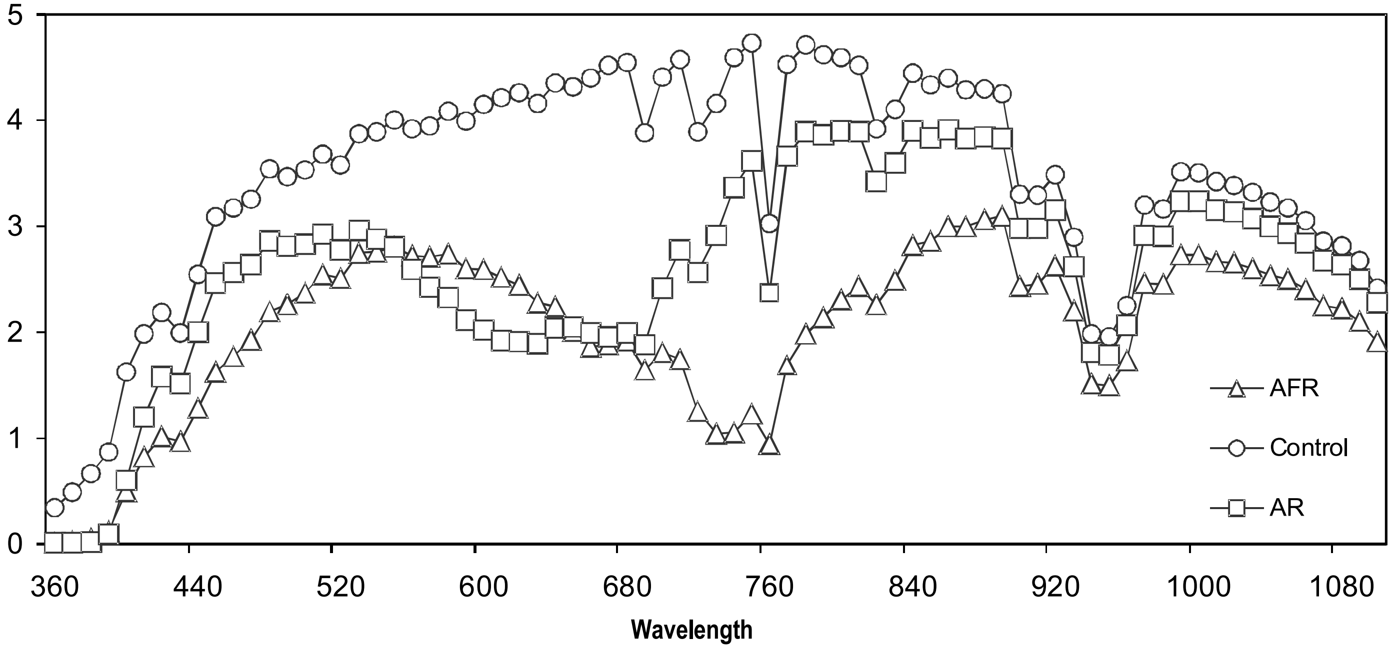

Fig. 1. Spectral transmission properties of A_{FR} (far-red light absorbing) and A_R (red light absorbing) photoselective films. Control film was clear polyethylene film.

All plants were top-dressed at a standard rate of 15 g/pot of 15N-3.9P-10K Osmocote Plus® (The Scotts Co., Marysville, OH). Plants were transferred to experimental chambers (90 x 60 x 60 cm) framed with PVC pipe and covered with photoselective (A_{FR}), photoselective (A_R) or non-photoselective (control) polyethylene films (Mitsui Chemicals, Inc., Japan). One fan was placed in each chamber with the opposite end slightly rolled up to ensure proper airflow and prevent heat build-u p. Stability of spectral distribution was verified by measuring light quality at the beginning and end of the experiment (Table 1, Fig. 1) using a LI-1800 spectroradiometer (Li-COR Inc., Lincoln, NE). The photosynthetic photon flux (PPF) inside each chamber was adjusted to 181 ± 29 µmol m^{-2} s^{-1} (indigo spires sage), 163 ± 30 µmol m^{-2} s^{-1} (wine sage), and 276 ± 30 µmol m^{-2} s^{-1} (Mexican sage) using cheesecloth. Plants were inspected daily and hand watered as and when needed. Average minimum and maximum temperatures in the greenhouse were 17.0 and 35.2°C (indigo spires sage), 18.5 and 32.1°C (wine sage), and 22.9 and 33.6°C (Mexican sage), respectively.

Table 1. Red:far-red (R:FR)^z ratios and estimated phytochrome photoequilibrium (Pfr/P)^y of solar light transmitted through photoselective films

Treatment	R:FR	(Pfr/P)
A_{FR}	1.39	0.76
A_R	0.62	0.65
Control	0.99	0.71

A_{FR} = Far-red light absorbing film, A_R = Red light absorbing film. Control film is a clear polyethylene film.

^{z}R = 600-700 nm waveband red light; FR = 700-800 nm waveband far-red light.

^{y}Estimated as described by Sager *et al.* (1988); Pfr = far-red absorbing form of phytochrome, P = total phytochrome.

Evaluation of plant responses: Plant height (height from media level to apex), number of fully expanded leaves, leaf area, leaf color, flower number and dry weight of leaves, stems and flowers, and roots were recorded at 6 weeks. Leaf greenness was measured on the 4th, 5th, and 6th leaf apex of each plant using a Spad-502 chlorophyll meter (Spectrum Technologies Inc., Plainfield, IL). Leaf area was measured using a leaf area meter (LI-COR, LI-3000A, Lincoln, NE). The specific leaf dry weight (SLDW) and specific stem dry weight (SSDW) were calculated by dividing the leaf and stem dry weight by the leaf area and stem length, respectively. Flowering time was recorded when buds reached full color. Experimental film treatments were replicated twice within the greenhouse, six plants randomly placed in each replicate. Due to space constrictions, the experiment was conducted three times, each with a different salvia species. Data from each experiment 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

FR-absorbing films: Light transmitted through the A_{FR} film reduced plant height (stem length) by 35.8% (indigo spires sage), 17.3% (wine sage), and 21.4% (Mexican sage) as compared to the control film (Table 2, Fig. 2). Height reduction was detected at 4 weeks and more pronounced at 6 weeks (Fig. 3). This magnitude of height reduction is comparable or more pronounced than the 10-20% reduction previously reported for other ornamentals such as golden shrimp plant (*Pachystachys lutea* Nees.) and cat whiskers (*Orthosiphon stamineus*) (Wilson and Rajapakse, 2001) and snapdragon (*Antirrhinum majus* L. 'Tahiti Red') (Rajapakse *et al.*, 2000). In addition, height reduction comparable to that of perennial salvia has been reported for vegetables of the Cucurbitaceae and Solanaceae families when grown under similar FR-absorbing films (Rajapakse *et al.*, 1999; Li *et al.*, 2000). Reduced height of plants, grown under A_{FR} film was attributed to reduced average internode length (Table 2). For all salvia species tested, total leaf area was unaffected by A_{FR} film. Leaf greenness of plants grown under A_{FR} was reduced (indigo spires salvia), increased (wine sage) or similar

Fig. 2. Effect of A_{FR} (far-red light absorbing) and A_R (red light absorbing) photoselective films on plant growth of indigo spires sage **(A)**, wine sage **(B)**, and Mexican sage **(C)** at 6 weeks. Control film is polyethylene without light absorbing dye

(Mexican sage) as compared to the control film. Plants grown under the A_{FR} film (Fig. 2A,B,C) had less leaf and stem dry weight than plants grown under the control film (Table 2). Flower development (days to flower and flower number) was not significantly affected by the A_{FR} film, with the exception that indigo spires sage had less flowers at six weeks when compared to the control film. Flower initiation of indigo spires sage was sporadic. At 6 weeks, only 58% of plants grown under the A_{FR} film had flowered as compared to plants grown under the control film, of which 92% flowered (data not shown). The effect of photoselective films on flowering appears to be dependent on whether plants are photoperiodic. Flowering of cosmos (*Cosmos bipinnatus* L.), zinnia (*Zinnia elegans* L.), and chrysanthemum (*Dendranthema* x *grandiflorum* (Ramat.) Kitamura) (short day plants) was only slightly delayed (by 1-2 days) when grown under A_{FR} film; whereas, the flowering of snapdragon and petunia (*Petunia* Vilm.-Andr.) (long day plants) was delayed by as much as 7-13 days when grown under short

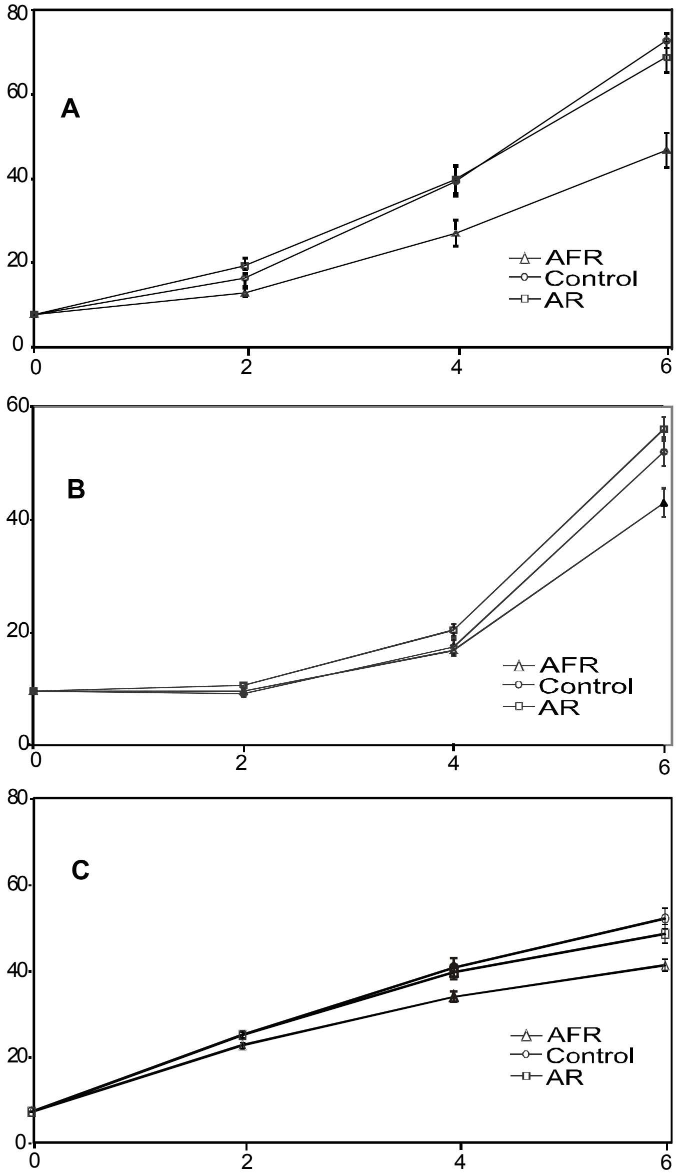

Fig. 3. Plant height of indigo spires sage **(A)**, wine sage **(B)**, and Mexican sage **(C)** over time. A_{FR} = Far-red light absorbing; A_R = Red light absorbing; Control is a clear polyethylene film. Vertical bars represent standard error.

days and by 2-3 days when grown under long days (van Haeringen *et al.*, 1998; Rajapakse *et al.*, 2000). Runkle and Heins (2001) reported that plants grown under a FR deficient filter had delayed flower initiation (but not development) in carpathian harebell (*Campanula carpatica* Jacq.) and canterbury bells (*Campanula* x *grandiflora* Hogg ex Sweet) and inhibited flower development (but not initiation) in pansy (*Viola* x *wittrockiana* Gams).

R-absorbing films: Regardless of species, light transmitted through the A_R film did not affect plant height (stem length), as compared to the control film (Table 2, Fig. 2). For all salvia species tested, total leaf area, leaf greenness, and flower development were unaffected by A_R film, with the exception that leaf greenness of indigo spires salvia grown under A_R was reduced, as compared to the control film (Table 2). Leaf and stem dry weights were reduced (indigo spires sage and Mexican sage) or unaffected (wine sage) by the A_R film, as compared to

Table 2. Growth characteristics of indigo spires sage, wine sage, and Mexican sage grown for 6 weeks under greenhouse photoselective films with varying red:far-red (R:FR)^z ratio

Species	Treatment	Plant height (cm)	Internode length (cm)	Leaf area (cm^2)	Leaf greenness (SPAD units)	Flower number	Days to flower	Leaf dry weight (g)	Stem dry weight (g)	Specific leaf dry weight (g cm^{-2})	Specific dry stem weight (g cm^{-1})
Indigo spires sage	Control	72.7 a^y	9.6 a	3046.2	39.3 a	4.8 a	.	5.3 a	4.7 a	0.0017 a	0.0644 a
	A_R	68.8 a	10.4 a	2803.7	37.2 b	3.8 a	.	4.5 b	3.9 b	0.0016 b	0.0559 b
	A_{FR}	46.7 b	4.8 b	2553.4	37.4 b	1.4 b	.	4.0 b	2.1 c	0.0016 b	0.0432 c
	Significance^x	**	*	NS	*	**		**	**	**	**
Wine sage	Control	52.0 a	4.26 a	2173	45.9 b	5.17	34.2	4.96	2.67 ab	0.0023	0.0494
	A_R	56.1 a	4.43 a	2321	45.8 b	5.83	32.2	5.21	3.27 a	0.0022	0.0579
	A_{FR}	43.0 b	3.41 b	2079	48.8 a	4.42	35.8	4.69	2.09 b	0.0022	0.0474
	Significance	**	*	NS	**	NS	NS	NS	*	NS	NS
Mexican sage	Control	51.5 a	2.73 a	1161	39.9	4.50	35.2	3.19 a	2.55 a	0.0027	0.0483
	A_R	47.3 a	2.37 b	1070	41.3	4.75	37.9	2.72 b	1.99 b	0.0025	0.0422
	A_{FR}	40.5 b	2.32 b	952	42.1	5.67	35.5	2.40 b	1.68 b	0.0026	0.0412
	Significance	**	*	NS	NS	NS	NS	**	**	NS	NS

A_R=red light absorbing film; A_{FR}=far-red light absorbing; control film is clear polyethylene ^{z}R = 600-700 nm waveband red light; FR = 700-800 nm waveband far-red light. ^{y}Means followed by same letter within species are not significant at *P* = 0.05. ^{x}NS, *,** Nonsignificant or significant response at *P* = 0.05 or 0.01, respectively.

the control film. This correlated to reduced (indigo spires sage) or similar (wine sage and Mexican sage) specific leaf and stem dry weights of plants grown under the A_R film, as compared to the control film.

Acknowledgements

The authors gratefully appreciate the technical assistance of Laurie Krumfolz, Florida Agricultural Experiment Station, Journal Series No. R-08653.

References

Burnett, S.E., G.J. Keever, J.R. Kessler, Jr. and C.H. Gilliam, 2000. Growth regulation of Mexican sage and 'Homestead Purple' verbena during greenhouse and nursery production. *J. Environ. Hort.,* 18:166-170.

Clebsch, B. 2001. Salvias cross the border. *Horticulture,* XCVIII (5):51-53.

Li, S., N.C. Rajapakse, R.E. Young and R. Oi, 2000. Growth responses of chrysanthemum and bell pepper transplants to photoselective plastic films. *Scientia Hort.,* 84:215-225.

Murakami, K., H. Cui, M. Kiyota, T. Yamane and I. Aiga, 1997. Control of plant growth by covering materials for greenhouses which alter the spectral distribution of transmitted light. *Acta Hortic.*, 435:123-130.

Rajapakse, N.C., R.E. Young, M.J. McMahon and R. Oi, 1999. Plant height control by photoselective filters: current status and future prospects. *HortTechnology,* 9:618-624.

Rajapakse, N.C., T. Cerny and S.B. Wilson, 2000. Photoselective covers for plant growth regulation. *FlowerTech.*, 3(8):32-35.

Runkle, E.S. and R.D. Heins, 2001. Specific functions of red, far red, and blue light in flowering and stem extension of long-day plants. *J. Amer. Soc. Hort. Sci.*, 126:275-282.

Sager, J.C., W.O. Smith, J.L. Edwards and K.L. Cyr, 1988. Photosynthetic efficiency and phytochrome photoequilibria determination using spectral data. *Trans. Amer. Soc. Agr. Eng.*, 31:1882-1889.

Smith, H. 1994. Sensing the light environment: the functions of the phytochrome family. *In*: R.E. Kendrick and G.H.M. Kronenberg (eds.). Photomorphogenesis in Plants. Kluwer Academic Publishers, Dordrecht, The Netherlands, pp. 377-414.

Sutton, J. and P. Picton, 1999. The Gardener's Guide to Growing Salvias. Timber Press, Portland, OR.

Van Haeringen, C.J., J.S. West, F.J. Davis, A. Gilbert, P. Hadley, R.G.C. Henbest, S. Pearson and A.E. Wheldon, 1998. The development of solid spectral filters for the regulation of plant growth. *Photochem. Photobiol.,* 64:407-413.

Wilson, S.B. and N.C. Rajapakse, 2001. Growth regulation of subtropical perennials by photoselective plastic films. *J. Environ. Hort.,* 19:65-68.