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

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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 Spire sage (Salvia x ‘Indigo Spire’) (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\textsubscript{FR} (FR light-absorbing film), A\textsubscript{R} (R light-absorbing film) and control (clear plastic film). Solar light transmitted through the A\textsubscript{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\textsubscript{R} film did not significantly affect plant height, regardless of species. Leaf area was not significantly affected by the A\textsubscript{FR} or A\textsubscript{R} film as compared to the control film, regardless of species. Leaf dry weight of plants grown under A\textsubscript{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\textsubscript{FR} or A\textsubscript{R} film as compared to the control film, with the exception that flower number of indigo spires sage was reduced when grown under A\textsubscript{FR} film. These results indicate that compactness of three perennial sages can be achieved by selective reduction of far-red wavelengths from sunlight.


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\textsubscript{FR}) and R (A\textsubscript{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 Spire’) (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).
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\textsubscript{FR}), photoselective (A\textsubscript{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-up. 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\textsuperscript{-2} s\textsuperscript{-1} (indigo spires sage), 163 ± 30 µmol m\textsuperscript{-2} s\textsuperscript{-1} (wine sage), and 276 ± 30 µmol m\textsuperscript{-2} s\textsuperscript{-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)\textsuperscript{2} ratios and estimated phytochrome photoequilibrium (Pfr/P)\textsuperscript{3} of solar light transmitted through photoselective films

<table>
<thead>
<tr>
<th>Treatment</th>
<th>R:FR</th>
<th>(Pfr/P)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A\textsubscript{FR}</td>
<td>1.39</td>
<td>0.76</td>
</tr>
<tr>
<td>A\textsubscript{R}</td>
<td>0.62</td>
<td>0.65</td>
</tr>
<tr>
<td>Control</td>
<td>0.99</td>
<td>0.71</td>
</tr>
</tbody>
</table>

\(A_{FR} = \) Far-red light absorbing film, \(A_{R} = \) Red light absorbing film.

Control film is a clear polyethylene film.

\(R = 600-700 \text{ mm wavelength red light; FR} = 700-800 \text{ nm wavelength far-red light.}\)

\(P_{fr} = \) far-red absorbing form of phytochrome, \(P_{n} = \) total phytochrome.

### 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.
Mexican sage) as compared to the control film. Plants grown under the A<sub>FR</sub> 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<sub>FR</sub> 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<sub>FR</sub> 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<sub>FR</sub> film; whereas, the flowering of snapdragon and petunia (Petunia Vil.-Andr.) (long day plants) was delayed by as much as 7-13 days when grown under short 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<sub>R</sub> 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<sub>R</sub> film, with the exception that leaf greenness of indigo spires salvia grown under A<sub>R</sub> 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<sub>R</sub> film, as compared to...
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<sub>R</sub> film, as compared to the control film.

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**References**


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)<sup>2</sup> ratio

<table>
<thead>
<tr>
<th>Species</th>
<th>Treatment</th>
<th>Plant height (cm)</th>
<th>Internode length (cm)</th>
<th>Leaf area (cm&lt;sup&gt;2&lt;/sup&gt;)</th>
<th>Leaf greenness (SPAD units)</th>
<th>Flower number</th>
<th>Days to flower</th>
<th>Leaf dry weight (g)</th>
<th>Stem dry weight (g)</th>
<th>Specific leaf dry weight (g cm&lt;sup&gt;-2&lt;/sup&gt;)</th>
<th>Specific stem dry weight (g cm&lt;sup&gt;-1&lt;/sup&gt;)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indigo</td>
<td>Control</td>
<td>72.7 a&lt;sup&gt;y&lt;/sup&gt;</td>
<td>9.6 a</td>
<td>304.2</td>
<td>39.3 a</td>
<td>4.8 a</td>
<td>5.3 a</td>
<td>4.7 a</td>
<td>0.0017 a</td>
<td>0.0644 a</td>
<td></td>
</tr>
<tr>
<td>spires</td>
<td>A&lt;sub&gt;R&lt;/sub&gt;</td>
<td>68.8 a</td>
<td>10.4 a</td>
<td>2803.7</td>
<td>37.2 b</td>
<td>3.8 a</td>
<td>4.5 b</td>
<td>3.9 b</td>
<td>0.0016 b</td>
<td>0.0559 b</td>
<td></td>
</tr>
<tr>
<td>sage</td>
<td>A&lt;sub&gt;FR&lt;/sub&gt;</td>
<td>46.7 b</td>
<td>4.8 b</td>
<td>2553.4</td>
<td>37.4 b</td>
<td>1.4 b</td>
<td>4.0 b</td>
<td>2.1 c</td>
<td>0.0016 b</td>
<td>0.0432 c</td>
<td></td>
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<tr>
<td>Wine</td>
<td>Control</td>
<td>52.0 a</td>
<td>4.26 a</td>
<td>2173</td>
<td>45.9 b</td>
<td>5.17</td>
<td>34.2</td>
<td>4.96</td>
<td>2.67 ab</td>
<td>0.0023</td>
<td>0.0494</td>
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<tr>
<td>sage</td>
<td>A&lt;sub&gt;R&lt;/sub&gt;</td>
<td>56.1 a</td>
<td>4.43 a</td>
<td>2321</td>
<td>45.8 b</td>
<td>5.83</td>
<td>32.2</td>
<td>5.21</td>
<td>2.67 a</td>
<td>0.0023</td>
<td>0.0579</td>
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<tr>
<td>Mexican</td>
<td>Control</td>
<td>51.5 a</td>
<td>2.73 a</td>
<td>1161</td>
<td>39.9</td>
<td>4.50</td>
<td>35.2</td>
<td>3.19 a</td>
<td>2.55 a</td>
<td>0.0027</td>
<td>0.0483</td>
</tr>
<tr>
<td>sage</td>
<td>A&lt;sub&gt;R&lt;/sub&gt;</td>
<td>47.3 a</td>
<td>2.37 a</td>
<td>1070</td>
<td>41.3</td>
<td>4.75</td>
<td>37.9</td>
<td>2.72 b</td>
<td>1.99 b</td>
<td>0.0025</td>
<td>0.0422</td>
</tr>
<tr>
<td>A&lt;sub&gt;FR&lt;/sub&gt;</td>
<td></td>
<td></td>
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<td></td>
<td>2.40 b</td>
<td>1.68 b</td>
<td>0.0026</td>
<td>0.0412</td>
</tr>
</tbody>
</table>

A<sub>R</sub>=red light absorbing film; A<sub>FR</sub>=far-red light absorbing; control film is clear polyethylene. <sup>x</sup>R = 600-700 nm waveband red light; FR = 700-800 nm waveband far-red light. <sup>y</sup>Means followed by same letter within species are not significant at P = 0.05. **NS,*** Nonsignificant or significant response at P = 0.05 or 0.01, respectively.