Customizing Crop Foliage Color With LEDs: Ornamental Crops

Researchers quantify the effects of end-of-production supplemental LED lighting on purple fountain grass and seed geraniums.

Figure 1. **A crop of purple fountain grass (*Pennisetum setaceum*) grown during the winter and early spring under low-light greenhouse conditions exhibits green to pale red/purple foliage.**

by **W. GARRETT OWEN** and **ROBERTO LOPEZ**

DO you find that your purple fountain grass (*Pennisetum setaceum* 'Rubrum') crop is often green to light purple? What if we told you there is a quick solution to enhance and darken the foliage of purple fountain grass or other floriculture crops? In this second article of a four-part series highlighting the multiple uses of high-intensity light-emitting diodes (LEDs), we will discuss our research methodology and findings for enhancing the foliage color of ornamental crops with end-of-production (EOP) supplemental lighting (SL) in the greenhouse.

Many ornamental crops that greenhouse and nursery growers produce vary in size, shape and color. These variables are often influenced by the growing environment. For example, leaf color (intensity, distribution or both) of ornamental crops such as purple fountain grass is a key component that often influences the consumer's perception and ultimately an impulse purchase. The red or purple pigmentation of purple fountain grass leaves is attributed to anthocyanins (flavonoids). The concentration of anthocyanins in foliage is dependent on greenhouse environmental conditions such as light quality and intensity and temperature.

Purple fountain grass growers often find that their crop is not as colorful (e.g., green or pale red/purple) during the winter and early spring due to low-light greenhouse conditions such as those found in northern latitudes (Figure 1) or from excessive hanging baskets above (Figure 2). What if they had the ability to customize the color of their purple fountain grass crop quickly?

Table 1. **Leaf $h°$ values of 'Black Velvet' geranium (*Pelargonium ×hortorum*) and 'Rubrum' purple fountain grass (*Pennisetum setaceum*) at initiation (day 0) and after 14 days of day-extension lighting (control) or end-of-production (EOP) supplemental lighting (SL) from high-pressure sodium lamps or light-emitting diodes (LEDs) providing 100 $\mu mol \cdot m^{-2} \cdot s^{-1}$ of 100:0, 0:100, 50:50 or 87:13 red:blue EOP SL.**

		LEDs Providing 100 $\mu mol \cdot m^{-2} \cdot s^{-1}$ (red: blue light)			
	Control	100:0	0:100	50:50	87:13
$h°$ 'Black Velvet' Geranium					
Day 0	116.5				
Day 14	40.8	15.2	8.7	11.8	11.8
$h°$ 'Rubrum' Purple Fountain Grass					
Day 0	121.6				
Day 14	91.0	57.1	3.7	44.7	61.2

In our previous article, "Customizing Crop Foliage Color With LEDs: Red Leaf Lettuce," we reported the use and practice of high-intensity LEDs of various sources and intensities for EOP (before harvest) SL to enhance and darken the foliage color of four commercially available red leaf lettuce varieties. We found that EOP SL can allow growers to manipulate the leaf color of the four lettuce varieties we tested in as few as five to seven days before harvest, thus increasing aesthetic appeal, quality and market value without negatively affecting growth or morphology of the crop.

Therefore, our objective for this article was to quantify the effect of EOP (prior to shipping) SL of different sources and intensities on foliage color of purple fountain grass and a seed geranium (with an almost zoned or dark-banded foliage with a contrasting green edge).

In Case You Missed It

Lighting Series, Part One:
Customizing Crop Foliage Color With LEDs: Red Leaf Lettuce

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Figure 2. **During the early spring, hanging baskets above greenhouse-grown purple fountain grass (*Pennisetum setaceum*) block sunlight and as a result foliage is green to pale red/purple in appearance.**

Ornamental Crop Production Methods

Seeds of 'Black Velvet' geranium (*Pelargonium* × *hortorum*) were sown into 72-cell plug trays filled with a commercial soilless medium and were irrigated as necessary with acidified water supplemented with water-soluble fertilizer to provide 50 ppm nitrogen (N). After 25 days, geranium seedlings and large liners (50-cell plug tray) of 'Rubrum' purple fountain grass (received from a commercial greenhouse) were transplanted into 5-inch diameter containers filled with a commercial soilless medium and were irrigated as necessary with acidified water supplemented with a combination of two water-soluble fertilizers to provide 200 ppm N.

Plants were grown in a double polyethylene-covered greenhouse at Purdue University, West Lafayette, Ind. To simulate a low ambient daily light integral (DLI) during winter months, plants were grown under a 50% black shade cloth, under a natural photoperiod and a constant air temperature set point of 69°F. The DLI and average daily temperatures (ADT) were 6 mol·m^{-2}·d^{-1} and 69°F ± 2.5°F, respectively.

Figure 3. **The colorimeter is a non-destructive instrument used by the U.S. food industry for measuring and tracking color changes of fruits and vegetables during processing and storage. In our study, we used the colorimeter to determine and track leaf color without damaging leaves or plants.**

End-Of-Production Supplemental Lighting

After 41 and 54 days from transplant, geranium and purple fountain grass plants were moved to another greenhouse and finished under a DLI of 9 mol·m^{-2}·d^{-1} and ADT of 71°F ± 1.1°F. Ten plants of each species were placed under a 16-hour photoperiod consisting of either ambient solar light plus day-extension light (control; no EOP SL) or EOP SL.

Day-extension lighting consisted of two [7:11:33:49 (%) blue:green:red:far-red] low intensity LED lamps providing 4.5 μmol·m^{-2}·s^{-1}. Supplemental light was delivered from 150-watt high-pressure sodium (HPS) lamps providing 70 μmol·m^{-2}·s^{-1} or one of six LED arrays providing either 100 μmol·m^{-2}·s^{-1} of monochromatic red [100:0 (%) red:blue] or 25, 50 or 100 μmol·m^{-2}·s^{-1} of monochromatic blue [0:100 (%) red:blue] or 100 μmol·m^{-2}·s^{-1} of one of two combinations of red and blue [87:13 or 50:50 (%) red:blue] light. End-of-production SL occurred for up to 14 days for geranium and 21 days for purple fountain grass.

At 0, 3, 5, 7, 14 or 21 days after initiating EOP SL, relative chlorophyll content (RCC) was estimated using a SPAD chlorophyll meter by measuring two recently matured leaves of each plant under each lighting treatment. As a result, the amount of chlorophyll present in the leaf or leaf greenness can be quickly estimated.

Additionally, leaf color of the same two recently matured leaves was measured using a portable tristimulus colorimeter

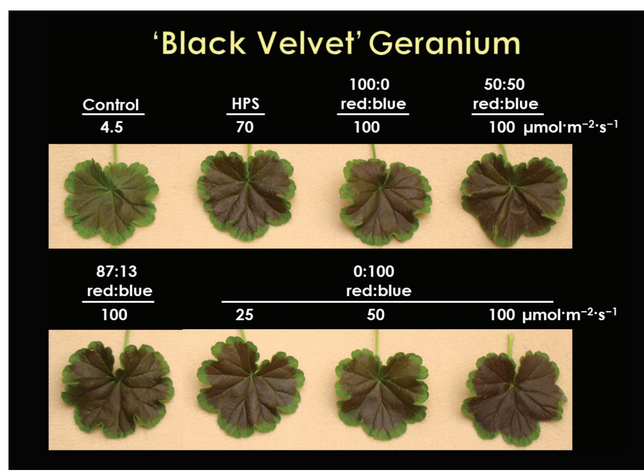

Figure 4A. **Leaf color of 'Black Velvet' geranium (*Pelargonium ×hortorum*) after 14 days of day-extension lighting (control) or end-of-production (EOP) supplemental lighting (SL) from high-pressure sodium lamps or light-emitting diodes (LEDs) providing monochromatic red, blue, or red:blue light at either low or high intensities.**

(Figure 3). Portable tristimulus colorimeters are used by the U.S. food industry for measuring surfaces and tracking color changes of fruits and vegetables during processing and storage. This instrument estimates the spectral reflectance properties such as lightness and chromaticity of fruit and leaf color without destruction or damage of leaves or plants.

For our study, we calibrated the portable tristimulus colorimeter analyzer to a standard white reflective plate (L* = 97.5, a* = 0.40, b* = 1.90) using the CIE (Commission Internationale de l'Eclairage) 1976 (L*a*b*) color coordinates. The L* value indicates darkness and lightness (black: L* = 0; white: L* = 100). Chromametric a* and b* values were recorded and were

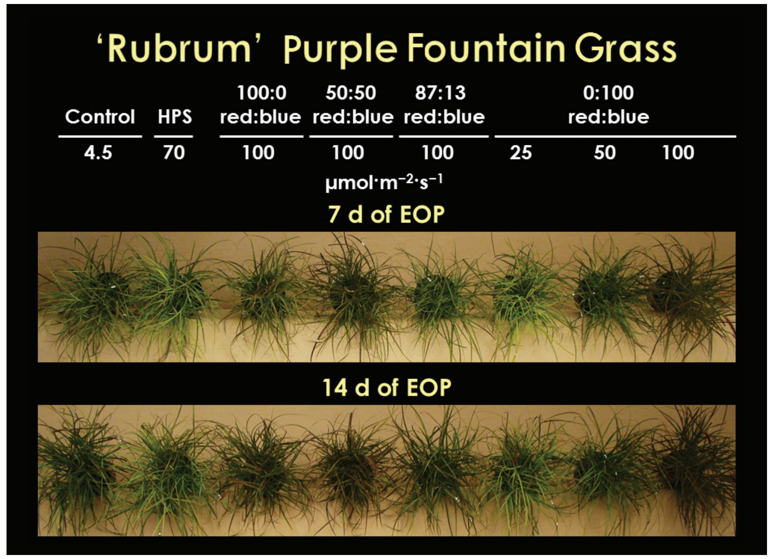

Figure 4B. **Leaf color of 'Rubrum' purple fountain grass (*Pennisetum setaceum*) after 7 and 14 days of day-extension lighting (control) or end-of-production (EOP) supplemental lighting (SL) from high-pressure sodium lamps or light-emitting diodes (LEDs) providing monochromatic red, blue or red:blue light**

used to calculate chroma (C*; saturation) and hue angle (*h*°; tone). On a circular scale, *h*° indicates redness (0°), yellowness (90°), greenness (180°) or blueness (270°) of the foliage.

EOP Supplemental Lighting Effects On Chlorophyll And Foliage

For both geranium and purple fountain grass, relative chlorophyll content (RCC) and foliage L* (lightness), C* (saturation) and *h*° (tone) values were significantly influenced by EOP SL and days of exposure to EOP SL. For geranium, EOP SL providing 100 $\mu mol \cdot m^{-2} \cdot s^{-1}$ of 100:0, 0:100, 50:50 or 87:13 red:blue light for 14 days resulted in increasing RCC and decreasing L* (darker foliage), C* (more saturated) and *h*° (red-purple foliage). Leaf *h*° values of 'Black Velvet' geranium under the control or 100 $\mu mol \cdot m^{-2} \cdot s^{-1}$ of 100:0, 0:100, 50:50 or 87:13 red:blue EOP SL for 14 days were 40.8°, 15.2°, 8.7°, 11.8° and 11.8°, respectively (Table 1, Figure 4A). Plants under the EOP SL 100 $\mu mol \cdot m^{-2} \cdot s^{-1}$ providing 0:100 red:blue light had the lowest *h*° values, indicating they changed from pale green/green (116.5) to a velvety red/dark maroon (8.7) after 14 days (Table 1).

For 'Rubrum' purple fountain grass, RCC increased from day three to 21 days after exposure when provided with EOP SL from the HPS lamps and from all LEDs delivering 100 $\mu mol \cdot m^{-2} \cdot s^{-1}$. EOP SL providing 100 $\mu mol \cdot m^{-2} \cdot s^{-1}$ of 100:0, 0:100, 50:50 or 87:13 red:blue light for ≥14 days resulted in increasing RCC and decreasing L* (darker foliage), C* and *h*° (red-purple foliage). For example, plants under the control or 100 $\mu mol \cdot m^{-2} \cdot s^{-1}$ of 100:0, 0:100, 50:50 or 87:13 red:blue EOP SL for 14 days resulted in *h*° values of 91.0°, 57.1°, 3.7°, 43.6°, 69.8°, respectively (Table 1; Figure 4B). Therefore, foliage color of plants under 0:100 red:blue EOP SL were the darkest red as the *h*° was the lowest (3.7; Table 1).

Based on our results, 'Black Velvet' geranium leaves varied in color, from velvety red to a dark maroon, whereas 'Rubrum' purple fountain grass leaves were dark to vivid red when plants were finished under 100 $\mu mol \cdot m^{-2} \cdot s^{-1}$ of 100:0, 0:100, 50:50 or 87:13 red:blue EOP SL. Our data suggests that 14 days of EOP SL providing 100 $\mu mol \cdot m^{-2} \cdot s^{-1}$ of 0:100 red:blue light enhanced pigmentation of 'Black Velvet' geranium and 'Rubrum' purple fountain grass leaves the most when plants are grown under a low greenhouse DLI <9 $mol \cdot m^{-2} \cdot d^{-1}$. **GG**

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