Great Lakes Fruit, Vegetable & Farm Market EXPO
Michigan Greenhouse Growers EXPO

December 5-7, 2017

DeVos Place Convention Center, Grand Rapids, MI

MSU Greenhouse / Floriculture Research Update

Where: River Overlook (upper level) Room A & B
MI Recertification credits: 1 (COMM CORE, PRIV CORE)
Moderator: Erik Runkle, Horticulture Dept., MSU

3:00 pm	Western Michigan Greenhouse and Metropolitan Detroit Flower Growers Joint Sponsored MSU Trial Garden Internship • Art Cameron, Horticulture Dept., MSU
3:10 pm	Evaluation of the Newly Registered Fungicide Mural Against Common Greenhouse Diseases • Blair Harlan, Plant, Soil and Microbial Sciences Dept., MSU
3:20 pm	Determining the Influence of Carrier Water Alkalinity and Greenhouse Air Temperature on the Efficacy of Ethephon PGR Spray Applications • Roberto Lopez, Horticulture Dept., MSU
3:30 pm	Determining the Effects of LED and HPS Lamp Supplemental and Photoperiodic Lighting on Bedding Plant Plug Quality • Roberto Lopez, Horticulture Dept., MSU
3:40 pm	Benefits of Including Far-Red Light in the Production of Floriculture Plugs • Yujin Park, Horticulture Dept., MSU • Erik Runkle, Horticulture Dept., MSU
3:50 pm	Developing Production Protocols for Potted Stevia • Ryan Warner, Horticulture Dept., MSU
4:00 pm	Session Ends

Sponsored by Sun Gro Horticulture

Part 1 of a four-part series on manipulating light quality, quantity, duration and carbon dioxide during plug production.

Producing High-Quality Plugs

How light quality, light quantity and carbon dioxide influence young plant production in greenhouses and indoor controlled environments.

Allison Hurt & Roberto Lopez

Every grower has their own protocol or recipe for producing plugs and rooted cuttings that works best with their growing environment, resources and needs. However, there's always room for improvement.

In this four-part series, we'll highlight our most recent greenhouse photoperiodic and supplemental lighting research utilizing light-emitting diodes (LEDs) during the production of both plugs and liners. Lastly, we'll introduce you to the exciting possibilities that exist with indoor vertical production of young plants utilizing sole-source LED lighting and carbon dioxide (CO_2) injection.

Over the last decade, our research has quantified the influence of light quantity and quality during young plant production on numerous ornamental species. Our general recommendation for most young plants is to provide 70 to 90 µmol•m^{-2}•s^{-1} of supplemental light to achieve a target daily light integral (DLI) of 10 to 12 mol•m^{-2}•d^{-1}. As a result, many growers are now producing young plants under supplemental lighting from high-pressure sodium (HPS) lamps, while others have made the investment in high-intensity LED fixtures (Figure 1A-D).

Most growers utilizing supplemental lighting report that production time is often reduced and that young plants are of higher quality (increased rooting, stem diameter and branching) and often flower earlier upon transplant. Additionally, when the ambient DLI is low (<7 mol•m^{-2}•d^{-1}) plugs of some species grown under LEDs providing ≥10% blue light are generally more compact (reduced leaf area and stem elongation), greener or have more pigmentation (anthocyanins) than those grown under HPS lamps or no supplemental lighting. Another group of growers use low-intensity LED photoperiodic lighting for 16 to 24 h•d^{-1} during young plant production and report reduced production time compared to no electric lighting (Figure 1E).

As the use of LED supplemental lighting increases, more questions surface. For example, since LEDs are much more energy-efficient to operate than HPS lamps, is there any benefit from running them continuously at a lower intensity even if the sun is out? Alternatively, is it more beneficial to run LEDs at a higher intensity in the morning, when it's cloudy and in the evening? There's value in addressing these questions, even though basic plant physiology tells us that plants can only utilize a certain quantity of light (light saturation point) for photosynthesis and anything beyond this is wasted energy.

Additionally, most commercially available LED fixtures only provide red and blue light, which can make plant observation a little more challenging, especially when it's dark. Therefore, we also wanted to determine how the addition of white light, mainly for human applications, would affect plug production.

Our objectives were to quantify plug quality and production time under 1) continuous 16-hour or instantaneous threshold supplemental lighting with HPS lamps or high-intensity LED top lighting; and 2) under low-intensity LED photoperiodic lighting with and without far-red light and compare these methods to plugs receiving no electric lighting.

The study

Seeds of *Petunia x hybrida* Ramblin' Peach Glow, *Impatiens walleriana* Accent Premium Salmon, *Gerbera jamesonii* Jaguar Deep Orange, wax begonia (*Begonia semperflorens* Bada Bing Scarlet) and tuberous begonia (*Begonia x tuberosa* Nonstop Rose Petticoat) were sown in 128-cell trays at a commercial greenhouse. One week later, trays were placed in a glass-glazed greenhouse at Michigan State University (MSU) in East Lansing, Michigan (lat. 40° N), with an air temperature set point of 72F (22C) and a vapor pressure deficit of 0.3 kPa maintained by injecting steam. Seedlings were hand irrigated as needed with reverse osmosis water supplemented with water-soluble fertilizer that provided 60 ppm nitrogen.

		Supplemental lighting				Photoperiod lighting			
	Control	HPS 16-h 70 µmol•m^{-2}•s^{-1}	HPS threshold 90 µmol•m^{-2}•s^{-1}	LED 16-h 70 µmol•m^{-2}•s^{-1}	LED threshold 90 µmol•m^{-2}•s^{-1}	Philips 16-h R:W:FR	Philips 16-h R:W	GE 16-h R:W:FR	GE 24-h R:W:FR
				Total no. of hours of operation					
Nov.-Dec.	0	448	357	448	357	448	448	448	672
Jan.-Feb.	0	448	403	448	403	448	448	448	672
Feb.-Mar.	0	448	319	448	319	448	448	448	672
				DLI (mol•m^{-2}•d^{-1})					
Nov.-Dec.	4.8	9.7	9.4	9.9	10.0	5.7	5.4	5.5	5.7
Jan.-Feb.	5.5	9.9	10.1	9.7	10.3	5.9	5.8	5.6	6.0
Feb.-Mar.	7.5	12.9	11.8	11.7	11.2	8.5	8.6	8.7	7.9

Table 1. The total hours of operation and daily light integral (DLI) for no electric lighting, threshold and 16-hour high-pressure sodium (HPS) and light-emitting diode (LED) supplemental lighting, and 16- and 24-hour photoperiodic lighting for the four-week study.

Plug trays were placed under each of nine lighting treatments that included a control (natural daylength with no electric lighting), four supplemental lighting treatments with either HPS or LED fixtures, and four photoperiodic treatments with LED lamps (Figure 2). Supplemental lighting treatments consisted of high-intensity 200-watt LED fixtures (Philips GP-TOPlight DRW-MB) providing a light ratio (%) of 10:5:85 blue:green:red (B:G:R) or 400-watt HPS lamps (P.L. Light Systems) providing a PPFD of 70 $\mu mol{\cdot}m^{-2}{\cdot}s^{-1}$ (on continuously for 16-h·d^{-1}).

These same HPS lamps and LED fixtures were also used in instantaneous threshold supplemental lighting treatments (on from 6:00 to 8:00 a.m. and 5:00 to 10:00 p.m. and only on between 8:00 a.m. to 5:00 p.m. when outside PPFD was <185 $\mu mol{\cdot}m^{-2}{\cdot}s^{-1}$ and switched off when >370 $\mu mol{\cdot}m^{-2}{\cdot}s^{-1}$) providing a PPFD of 90 $\mu mol{\cdot}m^{-2}{\cdot}s^{-1}$.

Photoperiodic lighting treatments consisted of screw-in low intensity 14-watt LED lamps providing 2 $\mu mol{\cdot}m^{-2}{\cdot}s^{-1}$ of a light ratio (%) of 6:15:77:2 B:G:R:far-red (Philips GreenPower LED flowering DR:W) or screw-in low intensity 15-watt LED lamps providing 7:12:35:46 B:G:R:FR (DR:W:FR) for 16-h·d^{-1} or 10-W LEDs providing 3:17:48:32 B:G:R:FR (GE Arize Greenhouse Pro Photoperiodic LED Lamp) for 16 or 24-h·d^{-1}.

Since our continuous supplemental lighting treatments (70 $\mu mol{\cdot}m^{-2}{\cdot}s^{-1}$) were on for 16-h·d^{-1} they operated a total of 448 or 672 hours during the four or six weeks of production, respectively (Table 1). In addition to sunlight, plugs under these treatments received an additional 5 $mol{\cdot}m^{-2}{\cdot}d^{-1}$ of supplemental lighting.

On the other hand, our threshold supplemental lighting at 90 $\mu mol{\cdot}m^{-2}{\cdot}s^{-1}$ provided 2.3 $mol{\cdot}m^{-2}{\cdot}d^{-1}$ as fixtures were on each day from 6:00 to 8:00 a.m. and 5:00 to 10:00 p.m. On very cloudy days, the lamps could potentially continue operating from 8:00 a.m. to 5:00 p.m. and provide an additional 4.2 $mol{\cdot}m^{-2}{\cdot}d^{-1}$ of supplemental light. During January and February, our threshold lamps ran for 403 hours and provided a very similar DLI during the four weeks of production (Table 1).

After four or six weeks (begonia only), plugs were subsequently transplanted into 4- or 4.5-in. pots filled with a commercial soilless media and finished in a greenhouse with an air temperature set point of 68F (20C) (petunia, begonia and impatiens) under the LED top lighting fixtures mentioned above or 72F (22C) under HPS lamps (gerbera).

Stay tuned for our second article in the four-part series where we'll share the results of our study looking at the effects of light quality, quantity and duration on plug production.

Allison Hurt is a M.S. student and Roberto G. Lopez is an Assistant Professor and Controlled Environment/Floriculture Extension Specialist in the Department of Horticulture at Michigan State University. The authors gratefully acknowledge Ball Horticultural Company and Syngenta Flowers for providing seed, C. Raker and Sons for seed sowing, Philips Lighting, HortAmericas, The Western Michigan Greenhouse Association, and The Metro Detroit Flower Growers' Association for funding, and Nathan DuRussel for greenhouse assistance.

Figure 1. Supplemental lighting of young plants utilizing A) high-pressure sodium lamps, B-D) various commercially available high-intensity light emitting diode (LED) fixtures or E) LED photoperiodic lighting.

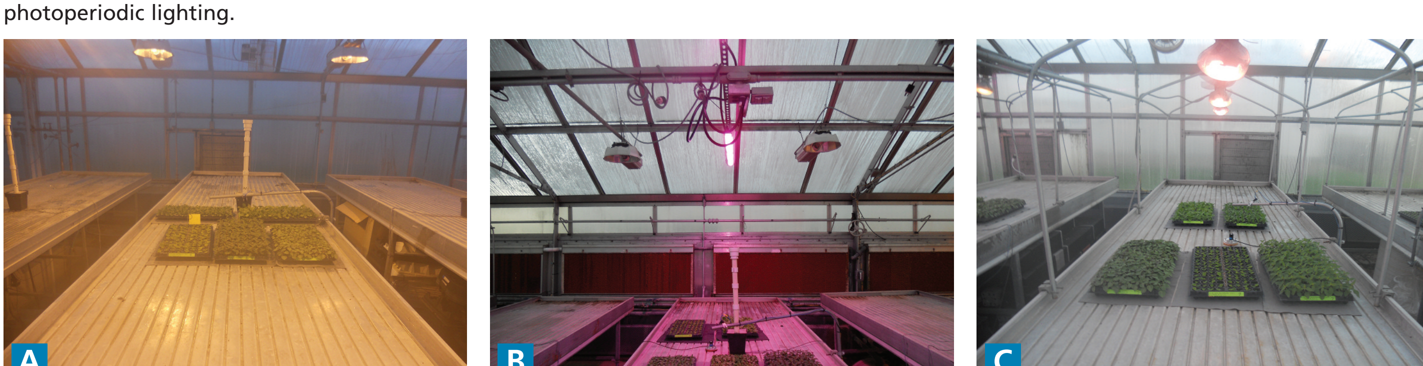

Figure 2. A) Examples of high-pressure sodium (HPS), B) light-emitting diode (LED) Top lighting and C) photoperiod treatments (wire mesh was used to reduce light intensity).

Benefits of Including Far-Red Light in the Production of Floriculture Plugs

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December, 2017

Introduction

Floriculture plug production is a valuable segment of the floriculture industry in Michigan. However, high greenhouse production expenses for heating and supplemental lighting, as well as daily and seasonal variability in weather conditions, challenge growers to produce consistently high-quality crops on schedule. Floriculture plugs can also be grown indoors under sole-source light-emitting diodes (LEDs), which enable control of the light spectrum to produce plants with desired attributes such as compact growth and early flowering. Most research with LED lighting has been performed on specialty food crops such as lettuce, usually with only blue (B, 400-500 nm) and red (R, 600-700 nm) LEDs, and benefits from including additional light wavebands have been tested on few crops.

Far-red (FR, 700-800 nm) light is outside the photosynthetically active waveband but regulates plant developmental processes. For example, extension growth increases as the proportion of FR light increases (as the R:FR ratio decreases). In some long-day plants, when FR light is provided with R light, flowering is accelerated. Thus, including FR light in an LED spectrum has the potential to control important quality attributes of floriculture crops. In this research, we investigated how including FR light in sole-source lighting regulates seedling growth and subsequent flowering in three floriculture crops.

Materials and Methods

Seeds of geranium ‘Pinto Premium Orange Bicolor’, petunia ‘Wave Blue’, and coleus 'Wizard Golden’ were sown in 128-cell plug trays by C. Raker & Sons and received at Michigan State University (MSU) one week later. Upon emergence of the first true leaves, the seedlings were thinned to one plant per cell. They were then grown under six sole-source LED lighting treatments with an 18-hour photoperiod in a refrigerated growth chamber at 68 °F. Six LED lighting treatments were provided with different mixture of B, R and/or FR LEDs to test the addition of FR light at two different photosynthetic photon flux densities (PPFDs) [96 $\mu mol \cdot m^{-2} \cdot s^{-1}$ (PPFD 96) and 288 $\mu mol \cdot m^{-2} \cdot s^{-1}$ (PPFD 288)] (Table 1). Seedlings were evaluated when ready for transplant, which was approximately 4 weeks after growing under the LEDs. Data collected included leaf area, stem length, and dry weight of shoots and roots.

Table 1. The intensities (in $\mu mol \cdot m^{-2} \cdot s^{-1}$) of blue (B, 400-500 nm), red (R, 600-700 nm), and far-red (FR, 700-800 nm) light, R:FR ratio, and FR fraction delivered from LEDs in six treatments.

	Lighting treatments					
Light waveband or ratio	1	2	3	4	5	6
B (peak = 447 nm)	32	32	32	32	32	32
R (peak = 660 nm)	64	64	64	256	256	256
FR (peak = 731 nm)	0	32	64	0	128	256
R:FR ratio	0:1	2:1	1:1	0:1	2:1	1:1
FR fraction [FR/(R+FR)]	0	0.3	0.5	0	0.3	0.5
Photosynthetic photon flux density (PPFD, 400-700 nm)	96			288		

In addition, at the end of the transplant stage, seedlings were transplanted into 4-inch pots and subsequently grown in a common greenhouse at 68 °F with a 16-hour photoperiod to determine whether the lighting treatments during the plug stage had any residual effects after transplant. For geranium and petunia, days to the first open flower from transplant, the number of visible buds or inflorescences, and stem length at flowering were evaluated; and for coleus, stem length at finishing stage was evaluated.

Results and Discussion

Stem elongation and leaf expansion. At both PPFDs, stem length of all species increased as FR light was added (Figure 1). The addition of FR also increased the total leaf area of petunia at both PPFDs. Leaf size increased in coleus only at lower PPFD. Generally, stem elongation and leaf expansion increased linearly as the portion of FR light increased (as the R:FR decreased).

Dry weight. Similar to stem elongation and leaf expansion, shoot dry weight (a good indicator of plant growth) of petunia and coleus increased linearly by up to 54% and 33%, respectively, as the portion of FR light increased at both PPFDs. In petunia, shoot dry weight increased with total leaf area at both PPFDs, indicating that inclusion of FR light can increase plant growth, at least partly by increasing leaf size. There was little or no effect of FR light treatments on root dry weight of any species.

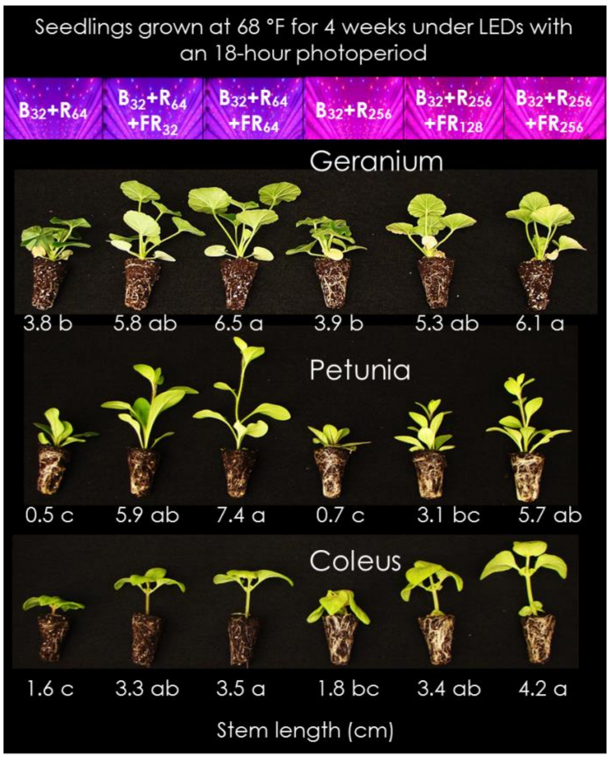

Figure 1. The effects of six sole-source LED lighting treatments on stem length (cm) at transplant. Values followed by different letters are significantly different.

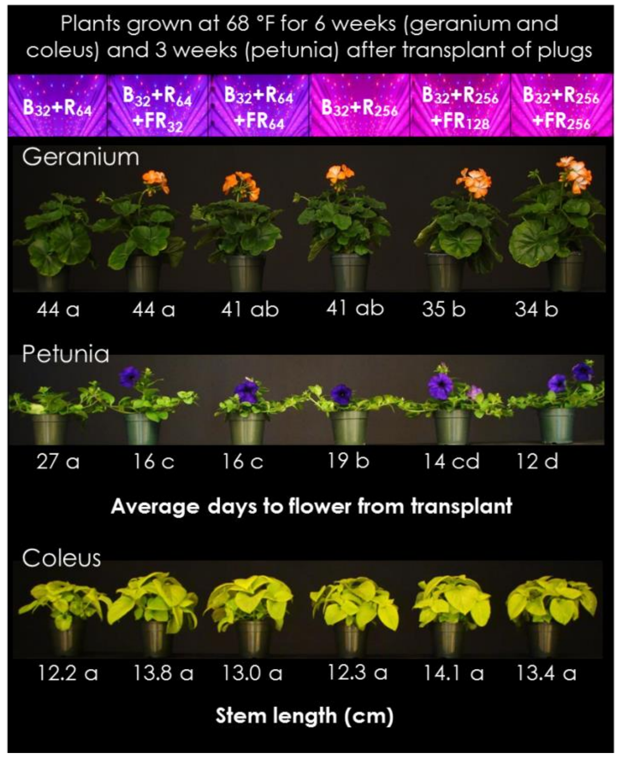

Figure 2. Average days to flower after transplant, or stem length, after plugs were grown under sole-source LED lighting treatments. Values followed by different letters are significantly different.

Subsequent flowering. In the long-day plant petunia, the addition of FR during the seedling stage accelerated subsequent flowering by 7 to 11 days at both PPFDs (Figure 2). At each PPFD, flowering was promoted similarly when the R:FR was 2 or lower. The magnitude of decrease in flowering time by the addition of FR light was greater under PPFD 96 (by 11 days) than under PPFD 288 (by 7 days). In day-neutral geranium, the addition of FR had no effect on flowering. However, the plants grown under the higher PPFD with FR light flowered 9 or 10 days earlier than plants grown under the lower PPFD without FR light. The lighting treatments had no effect on stem length at flowering in geranium and petunia or stem length at finishing stage in coleus.

Acknowledgements

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