e-GRO Research Update
January 2015, #2015-03

PURDUE UNIVERSITY

Using LEDs for Supplemental and Sole-source Lighting of Young Plants

by Roberto Lopez and Wesley Randall

Roberto G. Lopez
rglopez@purdue.edu

Peak young plant production (liners and plugs) occurs in late winter to early spring to meet spring and summer market dates. Unfortunately, this is also when the outdoor photosynthetic daily light integral (DLI) is at seasonally low levels, especially in northern latitudes. Research from Michigan State and Purdue Universities indicates a DLI of 10 to 12 $mol·m^{-2}·d^{-1}$ is needed to produce high-quality young plants that can withstand shipping and mechanical transplanting. However, the only way to effectively increase the DLI in a greenhouse to the levels needed to produce high-quality young plants is with supplemental lighting. High-intensity discharge (HID) lamps such as high-pressure sodium (HPS) and metal halide lamps have traditionally been used for supplemental lighting (Figure 1).

Both young and finish plant producers can benefit when young plants are produced under increased DLI from supplemental lighting. The benefits include, reduced production time and uniform, high-quality plugs and rooted cuttings that are compact, sturdy, and fully rooted. Additionally, plants flower faster when they are grown under higher DLIs during the young plant stage. Although high-intensity LEDs are still a relatively new technology, they have the potential to offer greater efficiencies, longer lifetimes, and wavelength specificity. For these reasons, LEDs have been used in plant research for a number of years, but have only recently surfaced for use in the commercial market for both supplemental and sole-source lighting. Therefore, the objectives of our study were to compare plugs of five bedding plant species grown under ambient solar conditions (≈6.5 $mol·m^{-2}·d^{-1}$), supplemental lighting (≈4.0 $mol·m^{-2}·d^{-1}$) from high-pressure sodium lamps (HPS), and LEDs in a greenhouse (total solar + supplemental

Figure 1. Traditional supplemental lighting of young plants with high-pressure sodium lamps.

Summary of Findings

- Geranium, petunia, and marigold seedlings grown under sole-source LED lighting were generally more compact (reduced stem length and leaf area), darker in foliage color (higher chlorophyll content), and had a higher root dry mass than those grown in the greenhouse under ambient or supplemental lighting.
- Supplemental and sole-source LED lighting with blue light generally suppresses stem elongation and leaf expansion and results in compact young plants which is often a desirable characteristic for plug growers.
- Multi-layer sole-source LED lighting could be used as an alternative to traditional greenhouse plug production.

Supported by

PHILIPS

HORT AMERICAS
www.hortamericas.com

DLI of area.≈10.5 mol·m^{-2}·d^{-1}). Additionally, we wanted to compare plugs of the same five species grown under sole-source light from LEDs in a multi-layer, indoor growth room (DLI of ≈10.5 mol·m^{-2}·d^{-1}).

The Experiment

Seeds of impatiens, marigold, petunia, vinca, and zonal geranium were sown into 288-cell plug trays filled with a commercial soilless substrate at Purdue University. Upon germination, two trays of each species were placed under ambient solar light (control; winter DLI in Indiana ≈6.5 mol·m^{-2}·d^{-1}) or 16 hours of supplemental light delivering 70 µmol·m^{-2}·s^{-1} (supplemental DLI of ≈4.0 mol·m^{-2}·d^{-1}) from HPS lamps (PL 2000; P.L. Light Systems Inc.,150-watt), or LED arrays (Philips GreenPower LED production module, 32-watt) providing (%) 87:13 red:blue light (Figure 1). Similarly, two trays of each species were placed in a multi-layer, growth room equipped with LED arrays providing 185 µmol·m^{-2}·s^{-1} from LEDs providing either 87:13 or 70:30 red:blue light (Philips GreenPower LED research module) for 16 hours (Figure 2). The spectral distribution of the supplemental and sole-source lights can be seen in Figure 4. Plugs were grown for 21 days (marigold and zonal geranium) or 28 days (all others) with a 73 °F day and night temperature set point. Upon germination, seedlings were hand irrigated with 100 ppm N (Jack's 16N–2P–15K LX Plug Formula for High Alkalinity Water).

In order to determine if there were any residual effects from supplemental or sole-source lighting, we transplanted plugs into 4.5 inch containers filled with a commercial soilless substrate and moved them to a common greenhouse finish environment with a day/night temperature set point of 68/65 °F. Plants were provided with a 16 hour photoperiod from ambient plus supplemental light from HPS lamps to achieve a target DLI of approximately 10 to 12 mol·m^{-2}·d^{-1}. Plants were hand irrigated as needed with 200 ppm N (3:1 mixture of Everris 15N–2.2P–12.5K and 21N–2.2P–16.6K, respectively).

Results

As expected, overall plug quality after 21 or 28 days was greatest for those seedlings grown under supplemental lighting compared those grown under ambient greenhouse light. For example, plugs of all five species were generally more sturdier (increased stem caliper), with a greater root and shoot dry mass.

Overall quality of plugs grown under sole-source light was

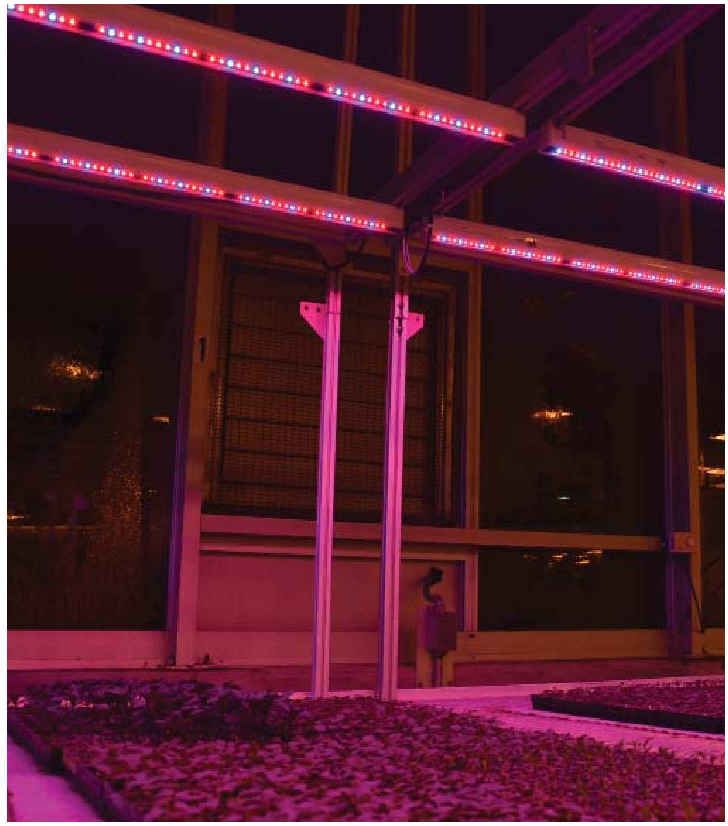


Figure 2. Greenhouse supplemental lighting of bedding plant plugs using LEDs delivering 70 µmol·m^{-2}·s^{-1} of (%) 87:13 red:blue light at canopy level.

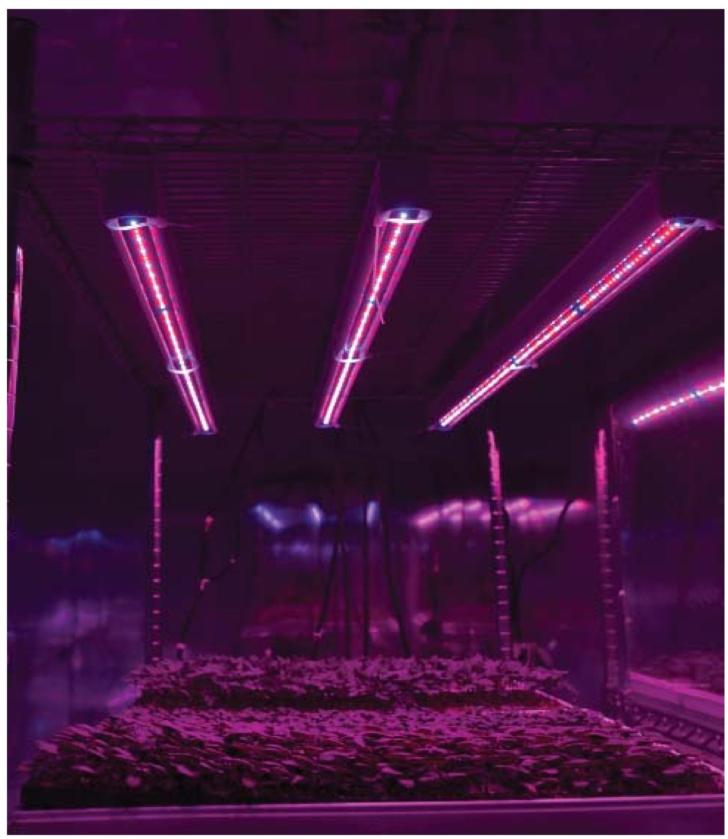


Figure 3. Multi-layer, sole-source indoor production of plugs using LEDs delivering 185 µmol·m^{-2}·s^{-1} of (%) 88:12 or 70:30 (not shown) red:blue light at canopy level.

generally similar or better (seedlings were generally more compact and had a reduced leaf area, were sturdier and had a greater root and shoot dry mass) than those grown under ambient or supplemental light in the greenhouse. For instance, stem length of geranium, petunia, and marigold seedlings was 5% to 26%, 62% to 79%, and 7% to 19% shorter, respectively, for seedlings grown under sole-source lighting compared to those under ambient and supplemental lighting (Figure 5 and 7). Under supplemental and sole-source lighting, stem caliper of geranium, impatiens, and vinca was 8% to 15%, 26% to 45%, and 12% to 17% greater, respectively, compared to those seedlings under ambient light (Figure 7). Additionally, root and shoot dry mass of all species was generally higher under HPS lamps and LED supplemental and sole-source lighting.

Finally, we wanted to determine if plants in the finish environment were influenced by supplemental or sole-source lighting received during the plug stage. Light treatment during the plug stage had mixed effects on time to flower (Figure 6 and 8). For example, time to flower of zonal geranium was similar for plugs grown under supplemental and sole-source light (Figure 8), but time to flower of bedding impatiens was delayed for plugs grown under sole-source light providing 88:12 red:blue light compared to the other light treatments. Additionally, time to flower of marigold and vinca was similar or reduced when plugs were grown under sole-source light compared to supplemental light. Similarly, height of plants at flower varied between species. Height of petunia at flower, was similar for plugs grown under supplemental or sole-source lighting (Figure 4) while height of vinca was reduced for plugs grown under sole-source light providing 70:30 red:blue light compared to other light treatments.

Conclusions

The results of this study indicate that plugs grown under LEDs in a greenhouse are of similar or better quality than those produced under HPS lamps. We also demonstrated that bedding plant plugs can be effectively grown under sole-source LEDs in multi-layer, vertical environmentally controlled rooms without negatively impacting the finished quality of the five species we tested. Additionally, from the results of this and previous research, supplemental and sole-source lighting with 10 to 30% blue light can suppress stem elongation and leaf expansion and results in compact young plants which is often a desirable characteristic for greenhouse growers

It is our recommendation that growers do their homework and are aware of the pros and cons of any supplemental or sole-source light system before investing in them. We also recommend that growers conduct their own studies to determine whether supplemental or sole-source lighting is a worthwhile investment for their operations.

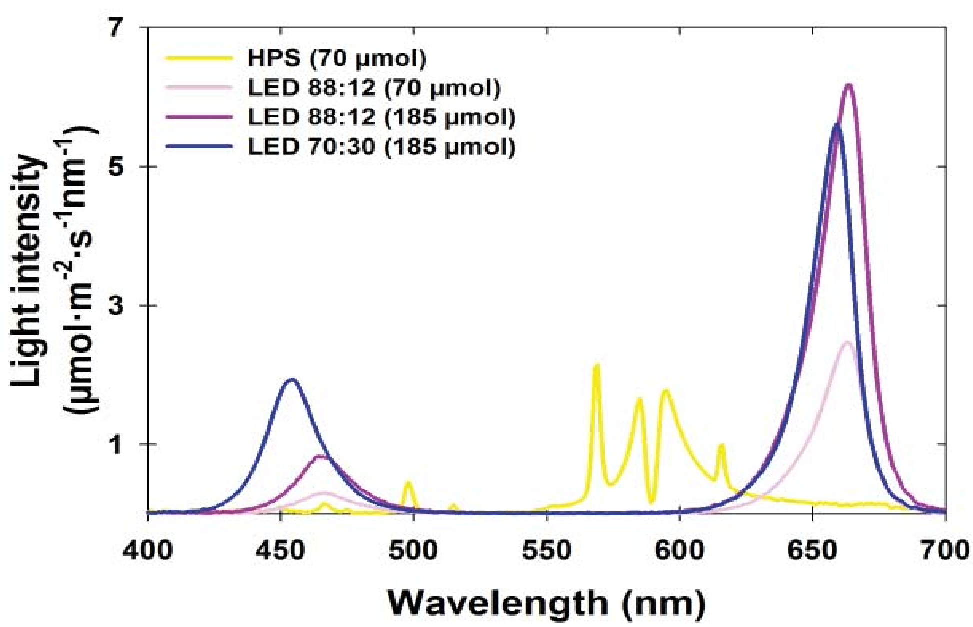


Figure 4. Light quality of high-pressure sodium (HPS) lamps delivering 70 µmol·m^{-2}·s^{-1}, light-emitting diodes (LED) delivering 70 or 185 µmol·m^{-2}·s^{-1} of (%) 87:13 red:blue light or 185 µmol·m^{-2}·s^{-1} of (%) 70:30 red:blue light at canopy level.

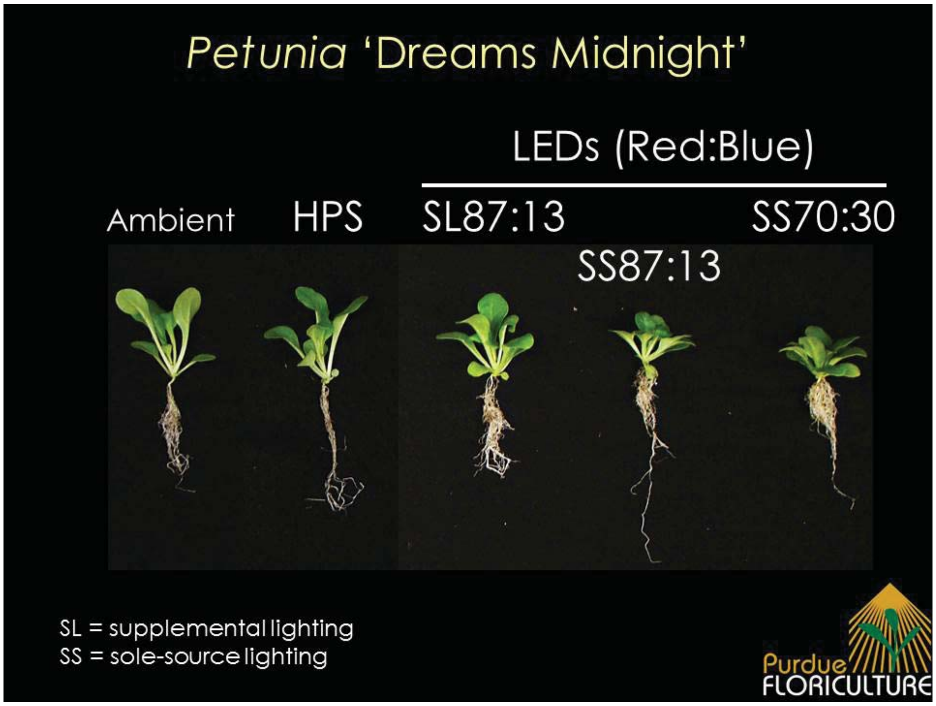
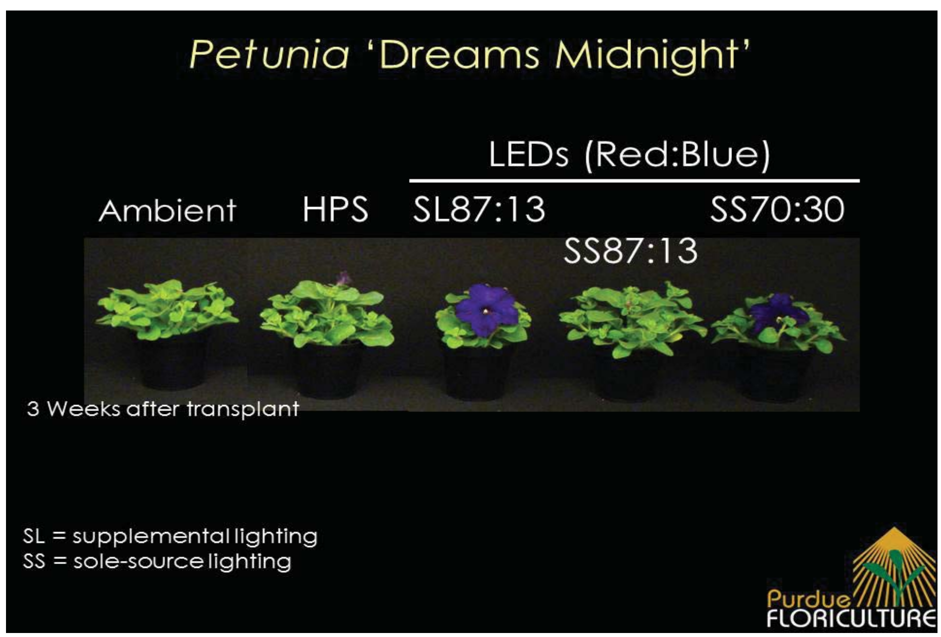


Figure 5. Plug quality of petunia plugs grown under ambient solar light, supplemental lighting (SL) from high-pressure sodium lamps (HPS) and LEDs (SL87:13) delivering 70 $\mu mol \cdot m^{-2} \cdot s^{-1}$ or sole-source (SS) LEDs (SS87:13 and SS70:30) in a multi-layer production system delivering 185 $\mu mol \cdot m^{-2} \cdot s^{-1}$.

Figure 6. Subsequent flowering of petunia after plugs were grown under ambient solar light, supplemental lighting (SL) from high-pressure sodium lamps (HPS) and LEDs (SL87:13) delivering 70 $\mu mol \cdot m^{-2} \cdot s^{-1}$ or sole-source (SS) LEDs (SS87:13 and SS70:30) in a multi-layer production system delivering 185 $\mu mol \cdot m^{-2} \cdot s^{-1}$.



We gratefully acknowledge Rob Eddy, Garrett Owen, Kristine Adamiec, Andrea and Alyssa Hilligoss, and Bryce Patz for greenhouse and laboratory assistance; the USDA-NIFA SCRI grant No. 2010-51181-21369 for funding; Philips Lighting and Hort Americas for funding and LEDs; and P.L. Light Systems for HPS lamps. We also thank Ball Horticultural Co. for seed. The use of trade names in this publication does not imply endorsement by Purdue University of products named nor criticism of similar ones not mentioned.

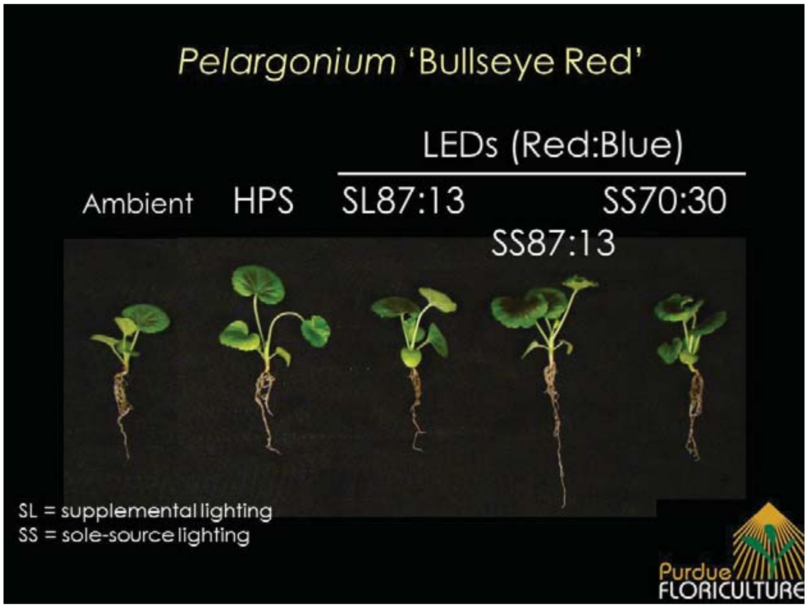
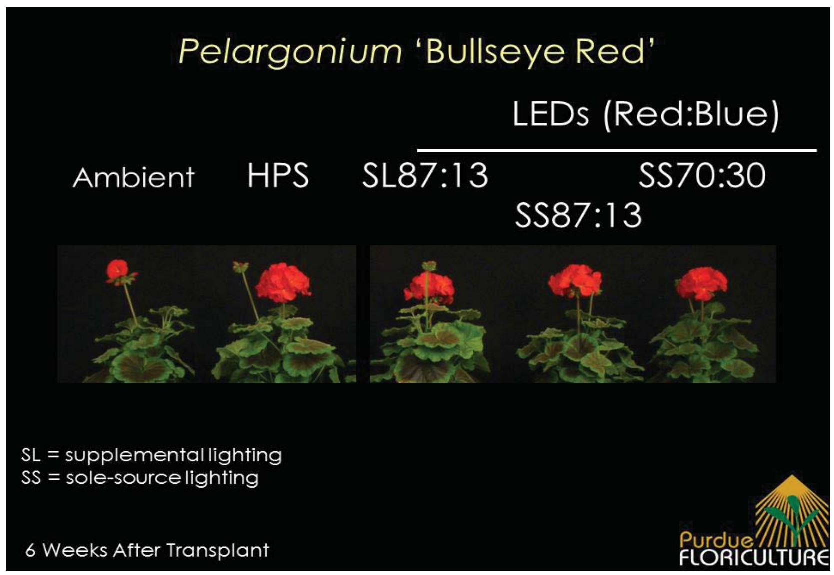


Figure 7. Plug quality of geranium plugs grown under ambient solar light, supplemental lighting (SL) from high-pressure sodium lamps (HPS) and LEDs (SL87:13) delivering 70 µmol·m^{-2}·s^{-1} or sole-source (SS) LEDs (SS87:13 and SS70:30) in a multi-layer production system delivering 185 µmol·m^{-2}·s^{-1}.

Figure 8. Subsequent flowering of geranium after plugs were grown under ambient solar light, supplemental lighting (SL) from high-pressure sodium lamps (HPS) and LEDs (SL87:13) delivering 70 µmol·m^{-2}·s^{-1} or sole-source (SS) LEDs (SS87:13 and SS70:30) in a multi-layer production system delivering 185 µmol·m^{-2}·s^{-1}.



Participating Universities

Michigan State University
Kansas State University
Virginia Tech Invent the Future
Iowa State University
NC State University
University of New Hampshire Cooperative Extension
Cornell University
Purdue University
The University of Georgia