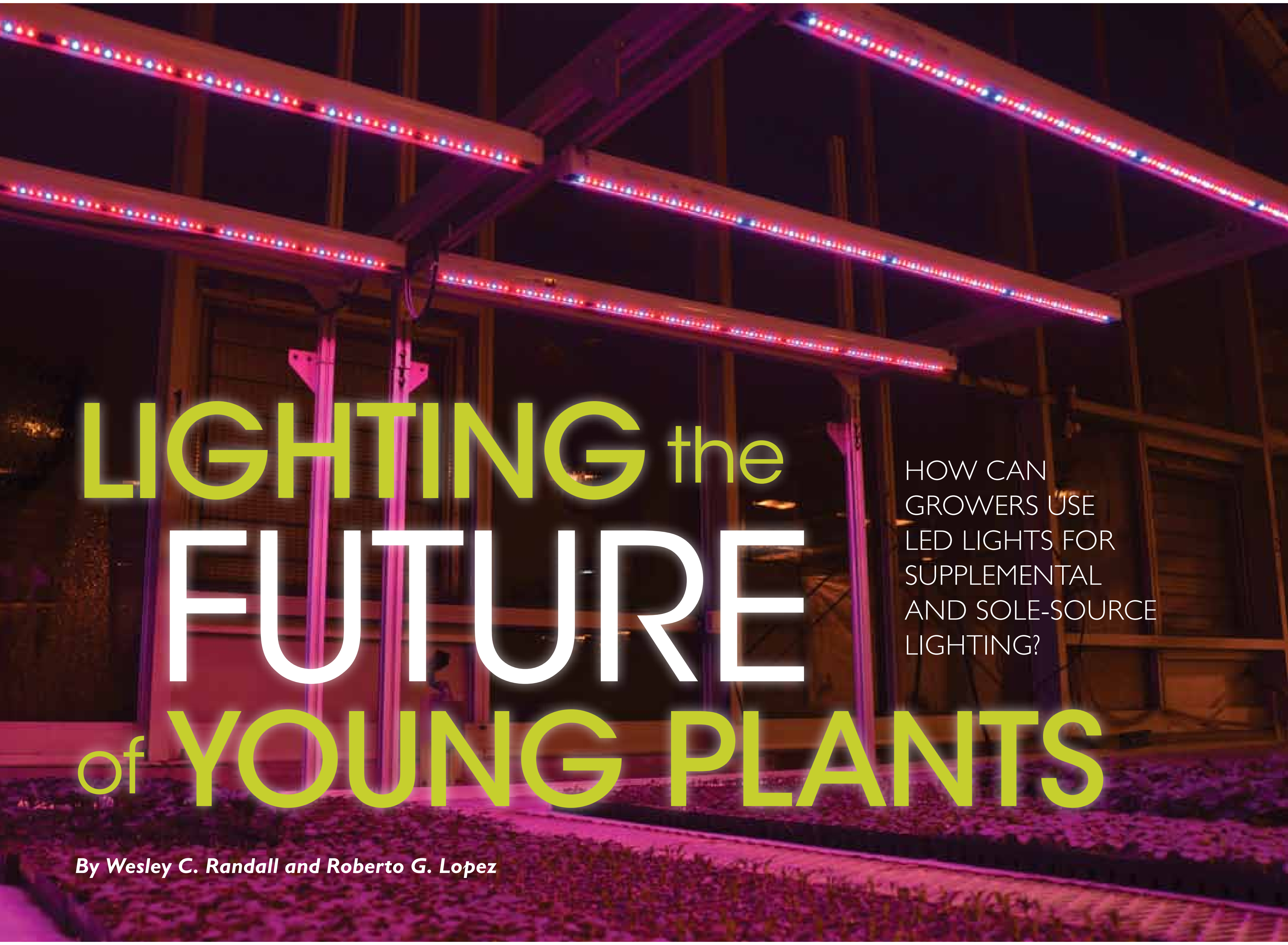

LIGHTING the FUTURE of YOUNG PLANTS

HOW CAN GROWERS USE LED LIGHTS FOR SUPPLEMENTAL AND SOLE-SOURCE LIGHTING?

By Wesley C. Randall and Roberto G. Lopez

Figure 1. Greenhouse supplemental lighting of plugs using LEDs delivering (%) 88:12 red:blue light with a photosynthetic photo flux (PPF) of 70 $\mu mol \cdot m^{-2} \cdot s^{-1}$ at canopy level.

Bedding plant plug production is an integral part of the floriculture industry. The bulk of production occurs in late winter or early spring to meet spring and summer sale dates. Unfortunately, this is also when the outdoor photosynthetic daily light integral (DLI) is seasonally low, and even lower in greenhouses. Research conducted at Michigan State and Purdue Universities indicates a DLI of 10 to 12 $mol \cdot m^{-2} \cdot d^{-1}$ is needed to produce high-quality young plants. However, supplemental lighting is the only way to effectively increase the DLI in a greenhouse to the levels needed to produce high-quality young plants (liners and plugs). Here we discuss the use of light-emitting diodes (LEDs) for greenhouse supplemental lighting and sole-source lighting for indoor vertical production of plugs.

It is well documented that both young and finish plant producers can benefit from young plants produced under supplemental lighting from high-pressure sodium (HPS) lamps. These include reduced production time and uniform, high-quality plugs and rooted cuttings that are compact, sturdy and fully rooted. It has also been established that plants flower faster when the DLI is increased 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 in the commercial market. However, because of their claimed high efficiency and versatility, interest in LEDs in the commercial greenhouse sector is on the rise as evident by the increase of available products in the marketplace. To date, relatively few published scientific studies have quantified the impact of using LEDs as supplemental light in greenhouse young plant production, or LEDs as sole-source light in multi-layer, vertical growth rooms. Therefore, our study sought to compare plugs of five popular bedding plant species grown under

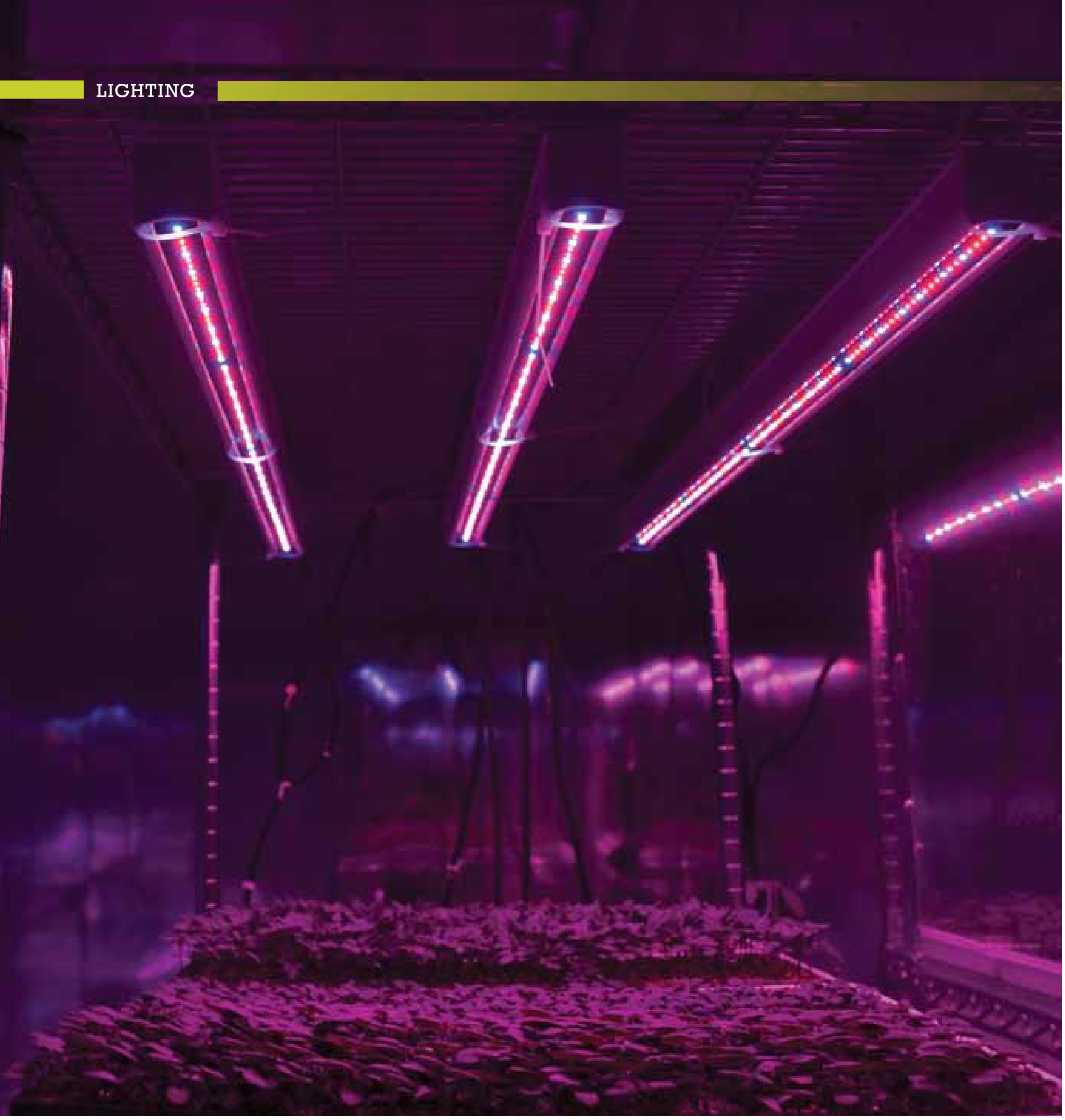

Figure 2. Sole-source indoor vertical production of plugs using LEDs delivering (%) 88:12 red:blue light with a photosynthetic photo flux (PPF) of 185 µmol·m^{-2}·s^{-1} at canopy level.

ambient solar conditions (≈6.5 mol·m^{-2}·d^{-1}), supplemental lighting (≈4.0 mol·m^{-2}·d^{-1}) from HPS lamps, plasma lamps (PL), and LEDs in a greenhouse (total solar + supplemental DLI of ≈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, vertical growth room (DLI of ≈10.5 mol·m^{-2}·d^{-1}).

The Study

Seeds of bedding 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) or 16 hours of supplemental light (70 µmol·m^{-2}·s^{-1}) from HPS lamps (150-watt), PL lamps (300-watt), or LEDs providing (%) 88:12 red:blue light. Similarly, two trays of each species were placed in a multi-layer, vertical growth room equipped with LEDs providing 185 µmol·m^{-2}·s^{-1} from either 88:12 or 70:30 red:blue light for 16 hours (Figure 2, above). The spectral distribution of the supplemental and sole-source lights can be seen in Figure 3 (right). 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 nitrogen (Jack's 16-2-15 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 nitrogen (3:1 mixture of Everris 15-2.2-12.5 and 21-2.2-16.6, respectively).

What We Saw

Our first objective in this study was to compare plugs grown under supplemental light to those grown under ambient solar conditions (control). As expected, overall quality after 21 or 28 days was improved for plugs grown with supplemental light compared to the control. Plugs of all species were generally more compact, sturdier (increased stem caliper), with a greater root and shoot dry mass for plants grown under supplemental lighting. Overall plug quality of marigold, petunia and vinca grown under LEDs was statistically similar to those grown under HPS lamps. For example, root dry mass of

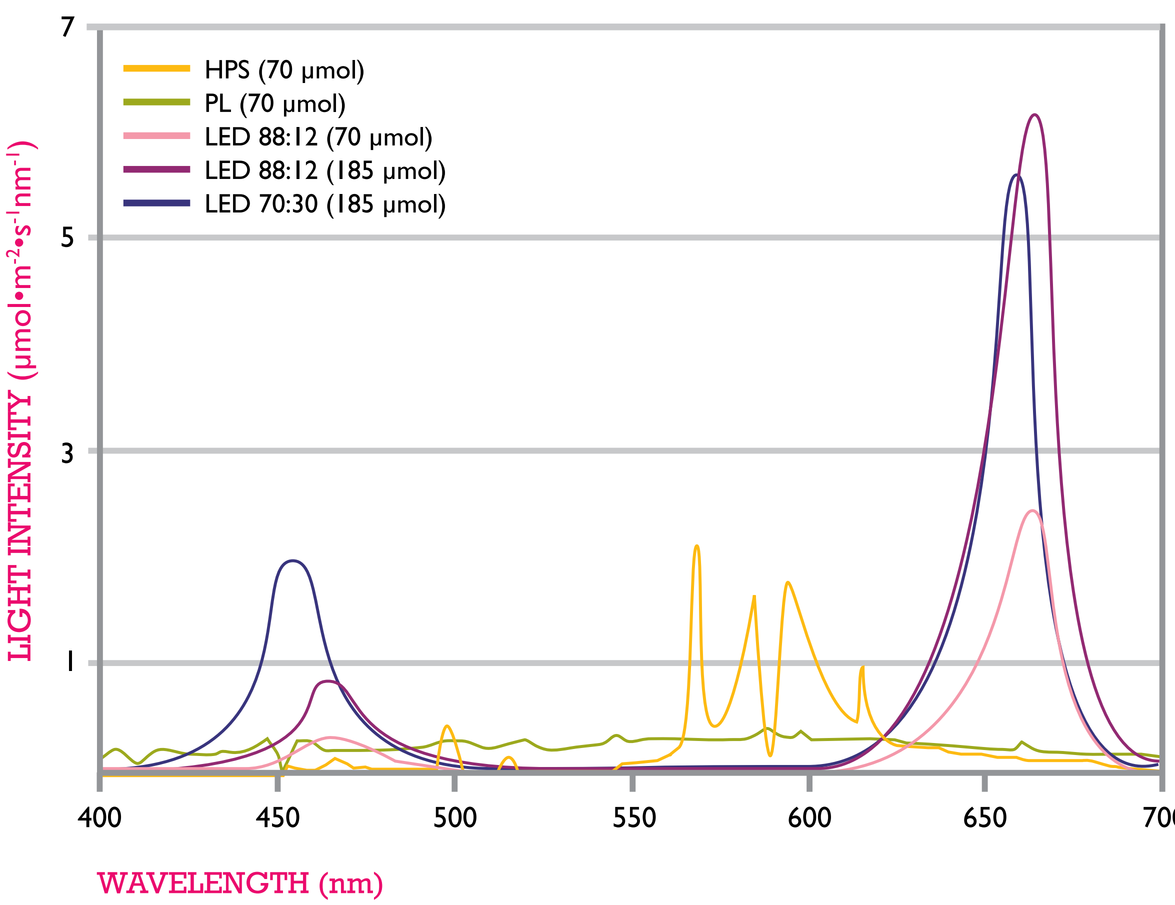

Figure 3. Light quality of high-pressure sodium (HPS) lamps, and plasma lamps (PL), light-emitting diodes (LED) delivering (%) 88:12 or 70:30 red:blue light with a photosynthetic photo flux (PPF) of either 70 or 185 µmol·m^{-2}·s^{-1} at canopy level.

vinca increased by 104 and 64 percent and 263 and 210 percent for marigold seedlings grown with supplemental light from HPS and LEDs, respectively, compared to the control.

Our second objective was to compare plugs grown under sole-source lighting to those grown under supplemental lighting providing the same DLI. Overall quality of plugs grown under sole-source light was generally similar or better (were generally more compact and sturdier with similar root and shoot dry mass) than those grown under supplemental light in the greenhouse. For instance, stem caliper of bedding impatiens grown under sole-source light was not statistically different from plants grown under supplemental light. Similarly, root dry mass of vinca was similar to plugs grown under sole-source light compared to those grown under supplemental light. Additionally, stem length of petunia was statistically shorter under both sole-source LED treatments compared to the supplemental lighting treatments (Figure 4); and zonal geranium had similarly increased stem caliper across both supplemental and sole-source light treatments (Figure 5).

Finally, we wanted to determine if plants in the finish environment were influenced by supplemental or sole-source lighting in the plug stage. Light treatment during the plug stage had mixed effects on time to flower. For example, time to flower of zonal geranium was similar for plugs grown under supplemental and sole-source light (Figure 5), 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

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Figure 4. Plug quality and subsequent flowering of petunia plugs grown under ambient solar light, supplemental lighting (SL) from plasma lamps (PL), high-pressure sodium lamps (HPS) and LEDs (SL88:12) delivering 70 $\mu mol \cdot m^{-2} \cdot s^{-1}$ or sole-source (SS) LEDs (SS88:12 and SS70:30) in a vertical production system delivering 185 $\mu mol \cdot m^{-2} \cdot s^{-1}$.

Figure. 5. Plug quality and subsequent flowering of geranium plugs grown under ambient solar light, supplemental lighting (SL) from plasma lamps (PL), high-pressure sodium lamps (HPS) and LEDs (SL88:12) delivering 70 $\mu mol \cdot m^{-2} \cdot s^{-1}$ or sole-source (SS) LEDs (SS88:12 and SS70:30) in a vertical production system delivering 185 $\mu mol \cdot m^{-2} \cdot s^{-1}$.

height of vinca was reduced for plugs grown under sole-source light providing 70:30 red:blue light and PL lamps 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 or PL lamps. Additionally, our study demonstrates that bedding plant plugs can be effectively grown under sole-source LEDs in multi-layer, vertical growth rooms without negatively impacting the finished quality of the five species we tested.

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.

Although high-intensity LEDs are still a relatively new technology, they have the potential to offer great efficiencies, longer lifetimes and wavelength specificity.

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