BY ERIK RUNKLE

Horticultural Lighting Applications

Lighting from electric lamps is increasingly being used in the production of horticultural crops grown in controlled environments. However, sometimes there is confusion about the different lighting applications and what type of lighting is needed to obtain the desired plant responses. Considering the cost to purchase, install and operate lighting can be expensive, it's important that the correct type of lighting is installed and delivered to plants. This article summarizes the different lighting applications and characteristics used in horticulture, including in greenhouses and indoors.

MICHIGAN STATE UNIVERSITY EXTENSION
FLORICULTURE TEAM

Erik Runkle is professor and floriculture Extension specialist in the department of horticulture at Michigan State University. He can be reached at runkleer@msu.edu.

Photoperiodic lighting. Many ornamental crops (annuals and perennials) flower in response to the length of the day and the night. When the nights are long (from late fall to early spring), the short days promote flowering of short-day plants and inhibit flowering of long-day plants. Photoperiodic lighting is the delivery of light, usually at a low intensity, to inhibit flowering of short-day plants and promote flowering of long-day plants (Table 1). Although this lighting application can increase the height of plants, it does not promote photosynthesis and thus, does not increase plant growth.

There are many ways to deliver photoperiodic lighting, but the most common method is to deliver 1 to 2 $\mu mol \cdot m^{-2} \cdot s^{-1}$ of light for four hours during the night (or at the end of the day) from lamps that at least partly emit red light. When the daily light integral (DLI) is low, both red and far red light are needed to promote flowering of a broad range of long-day plants. Once the days are sufficiently long (typically beginning in April), there is no value of photoperiodic lighting.

Supplemental lighting. When most plants are grown under a low DLI (e.g., less than 10 $mol \cdot m^{-2} \cdot d^{-1}$), growth of shoots and roots is slow and branching is poor. Supplemental lighting is the delivery of moderate-intensity lighting at night and on cloudy days to increase plant growth and plant quality attributes. High-pressure sodium is still the most common greenhouse lamp, but more energy-efficient LEDs are increasingly being used when their economics are favorable. Lamps typically operate up to 20 hours per day, but once the average DLI exceeds around 12 $mol \cdot m^{-2} \cdot d^{-1}$, there is little or no economic value to supplemental lighting on most crops, with the exception of some very high-light crops such as tomato.

Sole-source lighting. Some high-value crops, such as tissue culture propagules and leafy greens, are being grown indoors in which the only light source available to plants is from electric lighting. There are several reasons why the selection of lamp(s) used for this application is especially important:

- The intensity delivered is relatively high (150-200 $\mu mol \cdot m^{-2} \cdot s^{-1}$ for most crops, but even high for others), especially as plants reach the marketable stage.
- Lamps typically operate for 18 to 24 hours per day for most or all of the year.
- The light spectrum has a pronounced effect on plant growth and quality attributes.
- Cooling systems are needed to remove heat generated by the fixtures, so lamp efficacy (conversion of electricity into light) is especially important.
- Purchase and operation costs are high.

Considering these parameters, most new sole-source lighting installations are with LED arrays, especially red LEDs with blue or white LEDs, or a type of white LED alone. Research continues to better understand how different wavebands of light influence plant growth, as well as how they interact with each other and other environmental parameters. gpn

	Photoperiodic Lighting	Supplemental Lighting	Sole-Source Lighting
General description	Low-intensity lighting to regulate flowering of crops grown in greenhouses	Moderate-intensity lighting to increase photosynthesis of crops grown in greenhouses	High-intensity lighting for indoor production of high-value specialty crops
Primary objective	Promote or inhibit flowering	Increase growth, yield, and quality attributes	Precise regulation of plant growth and quality attributes
Major crops targeted	Ornamental crops	Plugs, liners, small fruits, vegetables, and other high-value crops	Leafy greens, herbs, young plants, small fruits, and other high-value crops
Operational use	When the natural photoperiod is less than 13 hours, and only during the night	When the daily light integral is low, and only at night and on cloudy days	Every day
Typical intensity (photon flux density)	1–2 $\mu mol \cdot m^{-2} \cdot s^{-1}$	60–120 $\mu mol \cdot m^{-2} \cdot s^{-1}$	150–200 $\mu mol \cdot m^{-2} \cdot s^{-1}$
Typical spectrum	Red ± Far red	Red + Blue/White or White	Red + Blue/White or White
Number of hours used per day	Usually up to 4	Usually up to 20	Usually 18 to 24
Control of plant size and shape (plant height and leaf size)	Slight to moderate	Slight	Strong

Table 1. The major lighting applications and characteristics used in the production of horticultural crops.