LED Grow Lights for Plant Production

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Introduction

Light is the single most important variable with respect to plant growth and development and is often the most limiting factor. Therefore, the use of grow lights in commercial greenhouses is beneficial for plants and growers. The reason for using grow lights varies and includes increasing light levels for plant photosynthesis or altering photoperiod. The duration of light a plant perceives is photoperiod. The different lighting sources that growers can use include incandescent (INC) lamps, tungsten-halogen lamps, fluorescent lamps and high intensity discharge (HID) lamps. Light emitting diodes (LED) are fourth generation lighting sources and are an emerging technology in horticulture. Below are advantages and disadvantages of LED.

LED Advantages

- Energy efficient
- Easy installation
- More durable
- Longer lifetime (less lamp changes)
- Low heat emission

LED Disadvantages

- Higher initial costs
- Heavier weight with some devices (e.g. grow lamps with heat sinks)
- Limited use (e.g. most LED devices are designed and used in research settings)
- Less coverage area
- Different ratios of LED colors
- High temperatures (of the environment) shorten lifespan and reduce efficiency

Before choosing a lighting device, several factors such as costs, efficiency, total energy emissions, life expectancy, light quality, light quantity, light duration and effect on plant growth and flowering should be considered. This Fact Sheet provides information about LED grow lights for use in plant production.

Design and Function

The design of LEDs varies and there are three main structural types, which are lead-wire, surface mounted and high-power LED. Despite the different designs, each type is mounted on a printed circuit board; therefore, LEDs function like computer chips. LEDs are solid-state semiconductors and when turned on or off, the action is instant. As for life expectancy (dim to about 70 percent from initial installation), LEDs can operate up to 50,000 hours. It is not necessary to replace single diodes or lamps constantly because LEDs do not burn out. Factors such as design, materials used and heat release affect life expectancy. Another important feature of LEDs is that heat does not escape from the surface, but through a heat sink which allows for close proximity between plants and LEDs (Figure 1). As for consumption of energy, LEDs are more efficient and use less energy than any other traditional greenhouse lights. In addition, operating costs and carbon emissions are lowered when using LEDs.

Devices and Bulb Types

There are different LED lighting devices (Figures 1, 2 and 3) and bulb types used in horticulture and each provide a specific need to plants and growers. Bulged reflectors,

Figure 1. Heat sink and standard E26 light bulb base fitting of Philips® GreenPower LED flowering lamp.

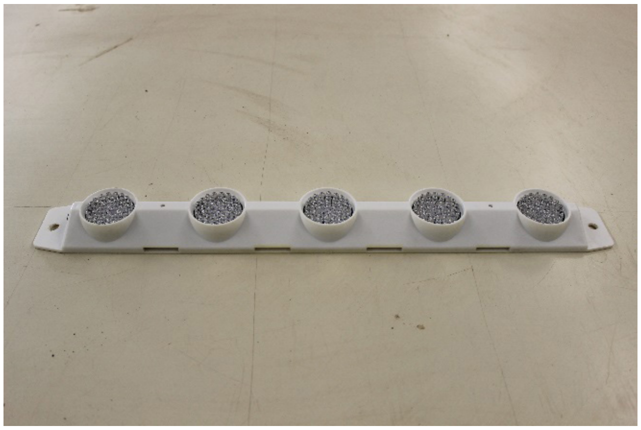

Figure 2. LED Grow Master's LGM550 light bar.

Figure 3. Philips® GreenPower LED flowering lamp.

tubular and miniature are the different bulb types. The different devices are toplights, inter-lights, tubular LEDs (TLEDs) and flowering lamps. Toplights, inter-lights and TLEDs are considered module lighting systems, which are for multi-layer production systems such as city (vertical) farming, tissue culture and indoor research facilities, such as grow rooms and growth chambers. Toplights have high lighting outputs and low heat emission and are used specifically for high wire and leafy vegetables. Interlights allow plants to receive light horizontally and vertically and are used for plants that rise such as cucumbers and tomatoes. TLEDs are replacement lamps for traditional fluorescent tubes used in tissue culture and offer more uniformed lighting and produce less heat. The latest type on the market are flowering lamps which are high-powered LEDs and have identical features as incandescent lamps such as a standard E26 light bulb base fitting (Figure1). For extending day length (photoperiod alteration) of plants, flowering lamps are ideal.

Light Emission and Quality

LEDs emit white and colored light. To make white light (used for general lighting), multiple colors are mixed together. The mixture can include a combination of blue (B), green (G), red (R), ultraviolet (UV) and yellow (Y). The colors are converted through a phosphor material coated on LEDs. During the conversion process, the phosphor material absorbs energy of short wavelengths (λ) and emits it at longer wavelengths. Emission of light from LEDs is narrow, reducing light pollution. Another great feature regarding color emission from LEDs is that the composition can be created or adjusted (color tuning) for specific plant responses. Depending on type, LEDs can emit wavelengths between 250 nm (UV) and 1,000 nm (infrared) or more, which is referred to as light quality and is related to photosynthetically active radiation (PAR). Wavelengths in the range of 400 and 700 nm are considered to be optimum for plants. However, 440 (B), 660 (R) and 730 (FR) nm are greatly optimized by most plants. Blue light increases chlorophyll production, resulting in healthier foliage. Red and far-red light promotes growth and flowering, which is useful for long-day plants under short-day conditions.

Light Measurements

Lumens, lux (lx) and foot-candles (fc) are units measured in plant light studies. However, studies using LED have replaced these units with photosynthetic photon flux (PPF), photosynthetic photon flux density (PPFD), and daily light integral (DLI). The most common units for measuring PAR are PPF and PPFD. The PPF is a measurement of total light amount produced each second by a lighting source and is expressed in micromoles per square meter per second ($\mu mol \cdot m^2 \cdot s^{-1}$). Depending on the device, PPF of LEDs can range between 13 and 2000 $\mu mol \cdot m^2 \cdot s^{-1}$. Another measurement, expressed in $\mu mol \cdot m^2 \cdot s^{-1}$, is the PPFD that measures the amount of light reaching a given surface. A PPFD between 400 and 800 $\mu mol \cdot m^2 \cdot s^{-1}$ is recommended for improved plant growth. Measurement of total light amount being delivered to

Table 1. Comparisons among lighting sources.

	LED	*HID*	*Incandescent*	*Fluorescent*
Lifespan	50,000 hours	24,000 hours	750 to 100 hours	10,000 hours
Watts	12 to 215	35 to 2,000	40 to 500	46 to 225
Ranking of Price Per Unit	Highest	High	Lowest	Medium
Energy Consumption	Lowest	Highest	Medium	Medium
Cost to Operate	Lowest	High	High	High
Efficiency	Very high	Medium	Low	Medium
Spectrum	Narrow and broad	Broad	Narrow	Broad

Table 2. Plant responses to LED spectra.

Lighting conditions	*Plant*	*Effects*	*Reference*
Red (660 nm)	Lettuce seedlings	Elongated hypocotyls and cotyledons	Hoenecke et al., 1992
Red (660 nm)	Strawberry (*Fragaria xananassa* L.)	Increased photosynthetic rates in leaves	Yanagi et al., 1996
Red (660 nm) + blue (470 nm)	Rice	Increased photosynthetic rates in leaves	Matsuda et al., 2004
Supplemented blue with 30 μmol·m^{-2}·s^{-1} PPF or red with 100 μmol·m^{-2}·s^{-1} PPF	Wheat seedlings	Restored chlorophyll synthesis	Tripathy and Brown, 1995
Infrared (880 nm and 935 nm)	Etiolated oat seedlings	Increased and decreased concentration of mesocotyl and coleoptile tissue respectively; straightened seedlings; activated gravitropism	Johnson et al., 1996
Red + white + far-red (700 to 800 nm) for night interruption	Dianthus (*Dianthus chinensis* 'Floral Lace Purple' and 'Super Parfait Strawberry')	Delayed flowering	Kohyama et al., 2014
	Petunia (Petunia xhybrida 'Easy Wave Burgundy Star')	Promoted early flowering	
	Dianthus, both cultivars	Promoted longer internodes (height)	
Red + white (600 to 700 nm) for night interruption	Ageratum (*Ageratum houstonianum* 'Hawaii Blue') and calibrachoa (*Calibrachoa* x *hybrida* 'Callie White')	Inhibited height	
Red:blue (100:0; 450 nm or 627 nm) with 70 μmol·m^{-2}·s^{-1} PPF	Petunia (*Petunia* x *hybrida* 'Suncatcher Midnight Blue') cuttings	Stem length shortened; increased dry mass of leaves, roots, and root:shoot ratio	Lopez and Currey, 2013
Sole source lighting of blue (446 nm) with 160 μmol·m^{-2}·s^{-1} PPF	Impatiens (*Impatiens walleriana* 'SuperElfin XP Red'), petunia (*Petunia* x *hybrida* 'Wave Pink'), salvia (*Salvia splendens* 'Vista Red'), and tomato (*Solanum lycopersicum* 'Early Girl') seedlings	Inhibited height	
Sole source lighting of red (634 nm and 664 nm) with 160 μmol·m^{-2}·s^{-1} PPF	Impatiens, petunia, salvia and tomato seedlings	Increased leaf area and fresh shoot weight	Wollaeger and Runkle, 2014

plants every day is DLI and is expressed as moles of photons per square meter per day (mol·m^2·d). The ideal DLI depends on the crop or species itself, as requirements of plants vary greatly as well as a grower's geographic location. A general DLI of 5 to 10, 10 to 20, 20 to 30, and 30 to 50 are ideal for low, medium, high and very high light plants, respectively.

In research, quantum sensors and spectroradiometers are devices used to measure these light parameters and are costly (pricing ~$1,000 or more). A cheaper alternative are light meters with a price range between $40 and $200.

Coverage Area and LED Placement

Light intensity (high light or low light) needs of a plant and total area of grow space determine how many LED watts (W) are needed. It is important to know because some LEDs do not operate at full capacity. It is recommended that for high light plants in a 1 square foot grow space to use 25 W and 16 W for low light plants. If a grower increases the square feet of a grow space, watts needed will increase as well. Placement of an LED refers to its distance from the plant canopy as well as the spacing between individual light units. Placement of an LED is based on the following:

- Plant type (e.g. high light or low light)
- Device type (e.g. toplights, inter-lights, TLEDs and flowering lamps)
- Coverage area
- Environmental conditions (e.g. natural lighting)
- Manufacturer recommendation

A rule of thumb to consider when placing LEDs is that the light from one device should overlap with the light from another, creating an even spread of light over the growth space to ensure proper plant growth.

Plant Growth and Flowering

LEDs are the ideal lighting type because growers can select them based on spectral output. Plants of all types and stages respond to a specific wavelength which enhances their development, quality and productivity. LEDs emitting R or FR are best for flowering ornamentals. Emission of B is ideal for vegetative growth. Vegetable and ornamental seedlings (plugs) as well as propagated plants (e.g. seeds, cuttings, and bulbs) respond well to R, B or R+B. An overview of different plant responses to light spectra is given in Table 2.

LED Manufacturers

There are several companies worldwide that manufacture LED products specifically for horticulture. The top selling companies are Philips (Amsterdam, Netherlands), Illumitex (Austin, TX, USA), Osram (Munich, Germany), and Cree Inc. (Durham, NC, USA) and LumiGrow (Emeryville, CA, USA).

Additional reading
https://www.ledgrowlightsdepot.com/blogs/blog/16326275-how-many-led-watts-are-required-per-square-foot-of-grow-space

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