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FACT SHEET

APRIL 2021 |

GREENHOUSE LIGHTING

With an increasing demand for local, year-round produce from consumers and an increasingly unreliable growing season, there has been a push towards indoor crop production and the adoption of artificial lighting. This factsheet looks to provide the basics on light to help make informed decisions about incorporating artificial lighting into your grow space.

What is light?

Light is electromagnetic radiation that has both particle and wave-like tendencies. For crop production, farmers typically focus on the wavelengths that drive plant growth (400-700 nm). This band of light is collectively called photosynthetically active radiation (PAR). PAR is directly involved in photosynthesis, which is the process that combines energy from the sun, carbon dioxide and water to produce sugars. These sugars, in turn, are then used to fuel plant growth.

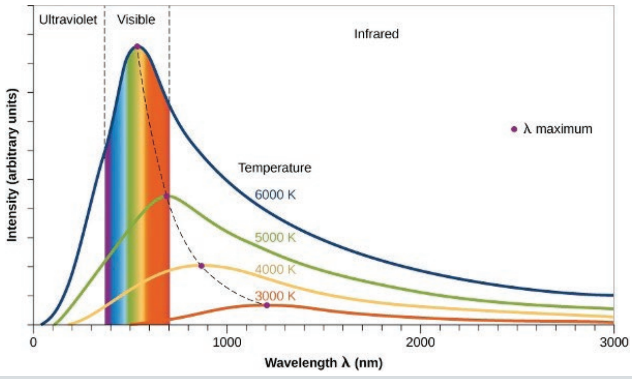

Figure 1. This image depicts the full spectrum of electromagnetic radiation. Notice how PAR, or visible light, only makes up a portion of the full spectrum. Image from Lumen Learning, Astronomy (**https://courses.lumenlearning.com/astronomy/chapter/the-electromagnetic-spectrum/**)

PAR can be further broken down into individual segments, which humans perceive as colour. Each segment has an impact on plant growth and development.

Blue light (400-525 nm): influences plant stature (photomorphogenesis) by controlling leaf and stem development, encourages the synthesis of pigments that protect the plants (antioxidants) and impacts flavour compounds. Blue light controls leaf flattening (phototropism) and plays a role in stomatal opening as well.

Green light (530 – 545 nm): primarily valuable for people: balances out the spectrum of light and facilitates more timely identification of insects, diseases and nutrient disorders.

Red light (660 nm): very efficient from a photosynthetic point of view and plays a big role in flower induction (short day versus long day plant).

While PAR is the driving force for sugar production and plant growth, it is important to consider the other regions of electromagnetic radiation when producing crops. Global solar radiation encompasses the full range of radiation given off by the sun (275 – 3000 nm). It is useful to understand total incident energy on the plants, as it greatly influences temperature and plant water use.

UV Region (275-400 nm): stimulates plants to produce anthocyanins and flavonoids and helps with insect (beneficials and pollinators) navigation.

Far-red light (700-780 nm): big impact on plants in terms of controlling flower induction and increases elongation of stems and cells.

Infrared (heat) region (780 – 3000 nm): provides heat to the plant, which speeds up internal reactions and overall growth.

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Units

Light is measured in many ways, and it is important to stay up to date on plant-focused metrics.

Traditionally light was measured in Lux and foot-candles. However, these units of measurement focused on human perception of light. By approaching light from the plant perspective, it can be utilized to its full potential to maximize production.

Commonly used units to describe horticulture lighting:

- PPFD - Photosynthetic Photon Flux Density; μmol/m^2/s
  - Number of photons striking a square meter per second
  - Also known as PAR intensity units
  - An instantaneous read on how much light being intercepted at that moment
  - Useful for spot-checking throughout the growing space
- DLI - Daily Light Integral; mol/m/day
  - An accumulation of PAR light intercepted throughout the day
- PPF – Photosynthetic Photon Flux; μmols/s
  - The total amount of PAR light that a light source emits each second
  - An important metric for calculating how efficient a luminaire is
  - Does not tell you how much of the measured light actually arrives at the plant
- PPE – Photosynthetic Photon Efficacy
  - Measures the amount of PAR light put out by a fixture (μmol/s) per unit of input power(watts)

You can convert PPFD values into DLI values by multiplying the PPFD value by the number of seconds the crop was exposed to the light.

- Thus 100 μmol/m^2/s PAR for 16 hours a day is 100 x 16 x 60 x 60 / (106) = 5.76 mol/m^2/day

This assumes that the instantaneous light level held steady throughout the day, which is not always the case. For a more accurate representation of the total PAR intercepted through the day, a microprocessor can be attached to your light sensor, which will then compute the DLI for that day while accounting for changes in PPFD (cloud cover, short rain events etc.).

Instruments

The ability to quantify light must be done using scientific equipment. Although very good at perceiving qualities of light (colours), the human eye is not equipped to measure quantity (intensity).

Light meters, solarimeters, or quantum sensors, are devices used to quantify light. Different models will have different ranges of radiation that can be intercepted and measured. Sensors can focus on a specific band of light (ex. PAR) or can be used to measure all the radiant energy from the sun. PAR encompasses 45.4% of solar radiation, and it is important to note that other wavelengths, although they are not directly involved in the photosynthetic process, have an impact on the overall growing environment. To capture the energy of the full spectrum from the sun, a light sensor that interprets 275 nm – 3000 nm is necessary. This is sometimes referred to as a global solarimeter. If using a global solarimeter, then a multiplication of the measured value x 0.454 will calculate an estimate of the amount of light measured within the PAR region. These light meters typically measure the instantaneous amount of radiation that is being intercepted.

These sensors can be purchased alongside other data loggers (temperature, humidity, wind speed, soil/substrate moisture sensors etc.), which then feed into a central location accessed by the main control computer for the production space.

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Why add lights?

Artificial lighting is a big investment for any operation, and there are many variables to consider.

When growing a crop, there will always be a limiting factor in the speed a plant grows. This limiting factor can be many things – temperature, light, water, nutrients, CO_2, humidity, etc.- so it is not just a matter of adding lights and seeing an exponential increase in plant growth. If the temperatures are too low, or insufficient water and nutrients are available, no amount of additional light will increase production. Identifying the limiting factor in the growing space is the first thing to when consider lighting up a grow space. If light is the limiting factor, then supplemental lighting could be a worthwhile investment.

By northern European standards, light is regarded as crop limiting when the DLI is <19.6 mol/m^2/day. Based on this standard, light levels in Nova Scotia limit production from late October until early March. Growers have verified this timeline, noting significantly more production in early March compared to January, despite a relatively constant temperature and no change to other growing parameters. For producers looking to grow year-round produce in a facility that relies on outdoor light, artificial lighting may be worth the investment.

The timeline provided above is based on historical outdoor radiation data. It is important to consider the impact of the greenhouse/tunnel covering. On average, plastic coverings filter out 22.5% of the incoming light. While an outdoor solarimeter may be measuring 19.6 mol/m^2/day, the actual reading inside the production space is 15.2 mol/m^2/day. It is key to set up monitoring equipment inside the production space to understand the crop environment. Relying on outdoor weather readings can be misleading and will impact the success of the crop.

Another major factor influencing this decision would be the target crop to be grown. Crops differ when it comes to the value of the final product. For lower-value crops, the price to light the space may exceed the price of the produce - this is a major deciding factor when it comes to implementing artificial lighting. Plants also differ in their daily light requirements. The production of greens requires relatively low light levels (DLI of 10-20), compared to flowering crops such as peppers and tomatoes (DLI of 20-40). A low-light crop will not need the same amount of light as a high-light crop, and this will influence whether additional light is required and how much needs to be added into the system.

The incorporation of lights into a production space is typically done in two ways. Adding luminaires into a glass or poly-covered space, which allows a high degree of natural light to pass through, is considered supplemental lighting. These lights function to increase day length during the winter, increase the amount of light the plants receive throughout the day, or enhance the natural spectrum (ex. supplementing additional blue light to keep the plants short in stature). The running time will vary on high light days compared to low light days, but the fixtures are there to improve on what is already present in the environment.

Figure 2. Here is an example of a producer that has chosen to implement supplemental lighting. While most of the light will come through the glass ceiling, the lights will be there to provide the plants with energy through the winter months. Photo credit: Talia Plaskett, Perennia

The second scenario applies to growing environments that are completely void of light. Sole-source lighting is used for indoor growing spaces, such as converted warehouses or shipping container farms, that do not receive any light from the outdoors. The light fixtures must provide a sufficient intensity and spectrum to drive photosynthesis and subsequently, plant growth. In this situation, lighting will make up a significant portion of the operation's overall energy use.

Figure 3. This is an example of an indoor grow room, where there is no natural light source. As a result, the grower must provide the plants with all the energy they need to grow. Photo credit: Talia Plaskett, Perennia

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Artificial Lighting

When it comes to supplementing light, there are different options available. Traditional luminaires, like High-Pressure Sodium (HPS), Metal Halide (MH), and Ceramic Metal Halide (CMH), were the best option on the market for a long time. While it has been around for a while now, LED technology has seen significant improvement in recent years and is now a popular option when it comes to supplemental lighting.

Traditional Luminaire	LED Luminaire
• Set in spectrum	• Option to customize/ change spectrum
• Lower price per fixture	• Higher price per fixture
• Costly to operate	• Highly efficient to operate
• Produce excess heat while running	• Less heat given off during operation compared to a traditional fixture
• Good at distributing light across the canopy - fewer fixtures needed for full coverage	• Limited light distribution across the canopy -more fixtures needed for full coverage
• Typically have a higher hang height (further away from the canopy)	• Typically have a lower hang height (closer to the canopy)
• Light penetrates the canopy well	• Light does not penetrate the canopy as effectively as a traditional fixture
• Regular maintenance and part replacement (lightbulbs, shields etc.)	• Less maintenance required through fixture lifetime
• Wider profile compared to LED lights, casting more of a shadow on the crop	• Have a thin profile, casting less of a shadow on the crop

Figure 4. A supplemental LED lighting system implemented in a cucumber crop. Notice the thin profile of the lights, which reduces the shadows cast on the crop from the overhead light. Compared to the traditional fixtures, we see a higher density of lights required to provide adequate energy to the crop. Photo credit: Talia Plaskett, Perennia

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Lighting Checklist

After deciding to pursue the addition of luminaires into a production space, there are a few things to consider.

1. **Do I need sole source lighting or supplemental lighting?**
2. **What type of luminaire do I want? Traditional fixture vs LED fixture**
   a. If LED lights, what spectrum do you want? The desired spectrum impacts the efficiency of the fixture: red LEDs are the most efficient but also the most expensive to produce (can cost up to 5x the amount of a white LED)
3. **Am I incorporating lights into an existing facility?**
   a. If yes, is the facility equipped to handle lights? (electrical capacity and outfitting, building structure and weight-holding capacity, HVAC/ venting capacity, hanging height of the lights etc.)
   b. If no, then be sure to consider the above factors when establishing a grow space.
4. **What is the efficiency of the fixture? How much light are you getting per unit of energy to run?**
5. **What is the cost per watt of a fixture?**
   a. Price for a 600W light compared to a 300W light.
6. **What are your light distribution needs?**
   a. The ratio of direct photons to diffuse photons produced by the fixture.
7. **Is this a lighting upgrade?**

Not every retrofit needs to be the movement towards LEDs: upgrading from magnetic to electronic fixtures can make a big impact

	6000 W PL 2000 (magnetic)	1000 W NXT2 (electronic)
# luminaires	360	150 (58% fewer fixtures)
Power consumption	216 kW	150 kW
Crop quality	-	Improved
Payback period	-	<1 year

Table from PL light systems, Optimizing lighting system webinar by Eric Moody

A key component to implementing a successful lighting system is the identification of a good supplier. One way to start identifying horticulture-specific lighting companies is the units used to describe light. If Lux or footcandles are used to describe the luminaires, these fixtures are not made with plant growth in mind. A reputable company should be able to assist in spectrum/fixture selection and come up with a lighting plan that makes sense for your space, crop, and lighting wish list. This plan should coordinate luminaire placement, illustrating distance and orientation between fixtures as well as in relation to the crop to maximize light output and distribution. The described conditions should come with a guarantee of light levels, light uniformity, and a maintenance/cleaning/ replacement regime to maintain a consistent and reliable grow space.