GREENHOUSE AND INDOOR PRODUCTION OF HORTICULTURAL CROPS

Determining the Economic Value of Providing Supplemental Light to Lettuce During Winter Production

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A greenhouse crop's light requirement (daily light integral, DLI) can vary greatly. Propagation materials (cuttings and plantings) can require 8-10 mol/m²/day, potted plants can require 10-15 mol/m²/day, leafy greens can require 15-20 mol/m²/day, and tomatoes and strawberries can require more than 20 mol/m²/day.

During the winter, greenhouse operations in Indiana and surrounding states grow propagation materials for spring planting and leafy greens for year-round supply. The DLI (which measures the total light received by plants in a day) received inside greenhouses from sunlight is approximately 5 mol/m²/day (Figure 1). Plant growth slows and their quality becomes poor (elongated) when sufficient DLI is not received. Therefore, it is necessary to provide supplemental lighting to grow quality plants in Indiana during the winter. However, many small growers in Indiana generally do not use supplemental lighting, because it adds to their equipment and energy costs.

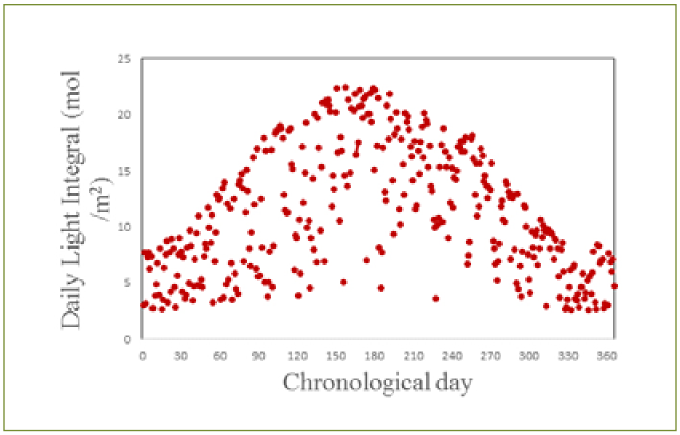

Figure 1. This graph shows the daily light integral received from sun light inside a greenhouse in West Lafayette, Indiana during a year. Note that light levels are usually lower than 10 mol/m²/day from November through February.

This publication aims to provide information to growers about estimating the costs and benefits when they use supplemental lighting. We will use hydroponic lettuce as an example throughout the publication, because it has an intermediate DLI requirement among greenhouse crops (15-20 mol/m²/day).

Determining the Costs

In Indiana and surrounding states, growers can raise lettuce in greenhouses during the winter for year-round supply to consumers. During the winter, the DLI received inside the greenhouse from sunlight is lower than the lettuce crop requires. For this reason, growers must provide supplemental lighting to produce a quality crop during the winter (Figure 2).

Supplemental lighting involves additional costs including investment on lighting fixtures and monthly costs for electricity. So, how do you know if supplemental lighting is economical for winter lettuce?

To answer this question, you need to know two things:

1. The cost of adding a mole of supplemental light
2. The added crop value produced from a mole of supplemental lighting

Figure 2. These pictures show the differences in the size and appearance of lettuce that receives sufficient and deficient DLI.

The Cost of Light

The cost of adding a mole of supplemental lighting in a *square meter* area is shown below.

You will need to calculate three things:

1. **The fixed cost per mole of light.** This cost includes the initial investment in light fixtures. First, calculate the moles of light received above the plants in one hour (or 3,600 seconds) using this formula:

$$\frac{\text{mol}}{\text{h}} = \frac{\text{Light intensity above plants (µmol/s) x 3,600 (s)}}{\text{1,000,000}}$$

Next, calculate the fixed cost ($) per mole of light received using this formula:

For example, a 320-watt LED lamp that costs $750 per fixture has a life span of 50,000 hours and 500 µmol/m²/s at a height of 4 feet below the lamps.

Using this information, you can calculate the moles of light received above plants:

And you can calculate the fixed cost per mole of light received:

$$\frac{\$}{\text{mol}} = \frac{750}{1.8 \times 50{,}000} = \$0.008 \text{ or } 0.8 \text{ cents per mole}$$

2. **The operational cost per mole of light**. This cost includes electricity charges for a mole of light. One unit of electricity is also called a kilowatt hour (KWh). A light fixture uses a unit of electricity (or KWh) when it uses 1,000 watts in one hour.

   To calculate operational costs, you will need to know how much power (or electrical input in kilowatts or KW) the lamps use, and you will need to know the unit cost of electricity.

   Calculate operational costs per mole of light using this formula:

$$\frac{\$}{\text{mol}} = \text{Cost of electricity} \frac{(\$)}{\text{KWh}} \times \text{Fixture power (KW)} \times \text{Time to produce a mole} \frac{(\text{h})}{\text{mol}}$$

   Using the above example and cost of electricity as $0.13/KWh, operational cost per mole of light is:

$$\frac{\$}{\text{mol}} = 0.13 \frac{(\$)}{\text{KWh}} \times \frac{320}{1{,}000} (\text{KW}) \times \frac{1}{1.8} \frac{(\text{h})}{\text{mol}} = \$\,0.023 \text{ or } 2.3 \text{ cents/mol}$$

3. **Cost per square meter of growing area.** Together, fixed and operational costs equal 0.8 + 2.3 = 3.1 cents per mole of light in a square meter of growing area.

The Value Added to Crops

After determining the cost of providing light, you need to determine the additional benefit each mole of supplemental light that you will provide to the crop. To obtain this information, we grew 15 varieties of lettuce under three daily light integral regimes of 5.6, 10.8, and 19.8 mol/m²/day for 28 days (a total of 157, 302, and 554 mol/m² of light during the growth). The average fresh weight of all varieties was 0.90, 2.1 and 6.7 lb/m² at harvest in the 5.6, 10.8 and 19.8 mol/m²/day treatments.

After analyzing the data, we estimated that lettuce can produce an additional fresh mass of about 0.0151 pound (or 6.8 grams) for every mole of light incident on the plants (Figure 3 — note the slope of the line in the graph). The slope of the line in the equation (0.0151 lb/mol or 6.8 g/mol) indicates the average weight produced per mole of light. Research by Kubota et al. (2016) reached similar results that indicate lettuce produces 3.7 to 6.9 grams per mole of light they receive.

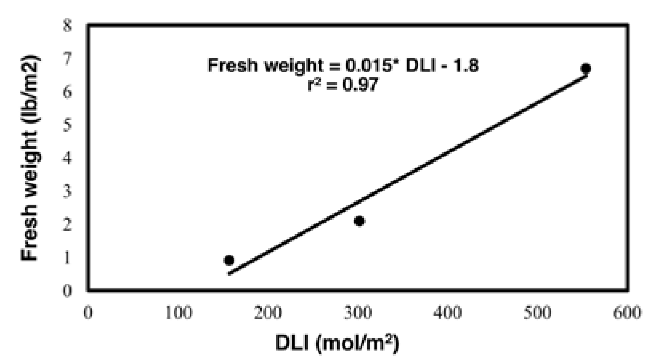

Figure 3. This graph shows the relationship between the average fresh weight (lb/m²) of 15 lettuce varieties and the total light (DLI, mol/m²) they received during the growth. The slope of the line in the equation (i.e., 0.015 lb/mol or 6.8 g/mol) indicates the average weight produced per mole of light.

If you multiply the average price per pound of fresh lettuce (this is your selling price in cents per pound) by 0.0151 lb/mole, you will get the added value (in cents) of lettuce produced per mole of added light.

For example, if the average price per pound of fresh lettuce is $2.50 (or 250 cents), then the added value from one mole of supplemental light is 250 cents x 0.0151 = 3.78 cents.

The cost of adding a mole of supplemental light was 3.1 cents while the benefit from the added crop value is 3.78 cents. In this example, there is a benefit to adding supplemental lights for winter lettuce production.

You can decide whether to add or use supplemental lighting based on the information on the cost and benefit of adding a mole of light. It is also important to remember that just adding light will not be enough; you have to make sure that other growing conditions are optimal, too.

Reference

C. Kubota, M. Kroggel, A.J. Both, J.F. Burr and M. Whalen. 2016. Does supplemental lighting make sense for my crop? – empirical evaluations. Acta Hortic. 1134: 403-411

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