Considering Supplemental Lighting? The following information may help you decide.

Introduction

Greenhouse growers producing crops during the late fall, winter, and early spring are faced with the question whether it makes economic sense to install a supplemental lighting system. For most crops, more light during these darker months means faster growth and better plant quality. But installing lamps and using the electricity to operate them is not cheap.

Available natural light

One way to determine the amount of light available for crop production at a particular location in the US is to consult the database of solar radiation data maintained by the National Renewable Energy Laboratory in Golden, Colorado (http://www.nrel.gov). This database contains solar radiation data for 239 locations across the US and its territories. Another way is to consult a local weather station (e.g., radio or TV station, airport) and ask for historic solar radiation data.

For plant production purposes, the solar radiation data can be converted into the units of mol/(m^2d), indicating the daily sum (integral) of light available for photosynthesis (PAR, 400-700 nm). For example, the monthly average light integrals for five locations across the US are shown in Figure 1 (1 kWh/(m^2d) = 7.49 mol/(m^2d)).

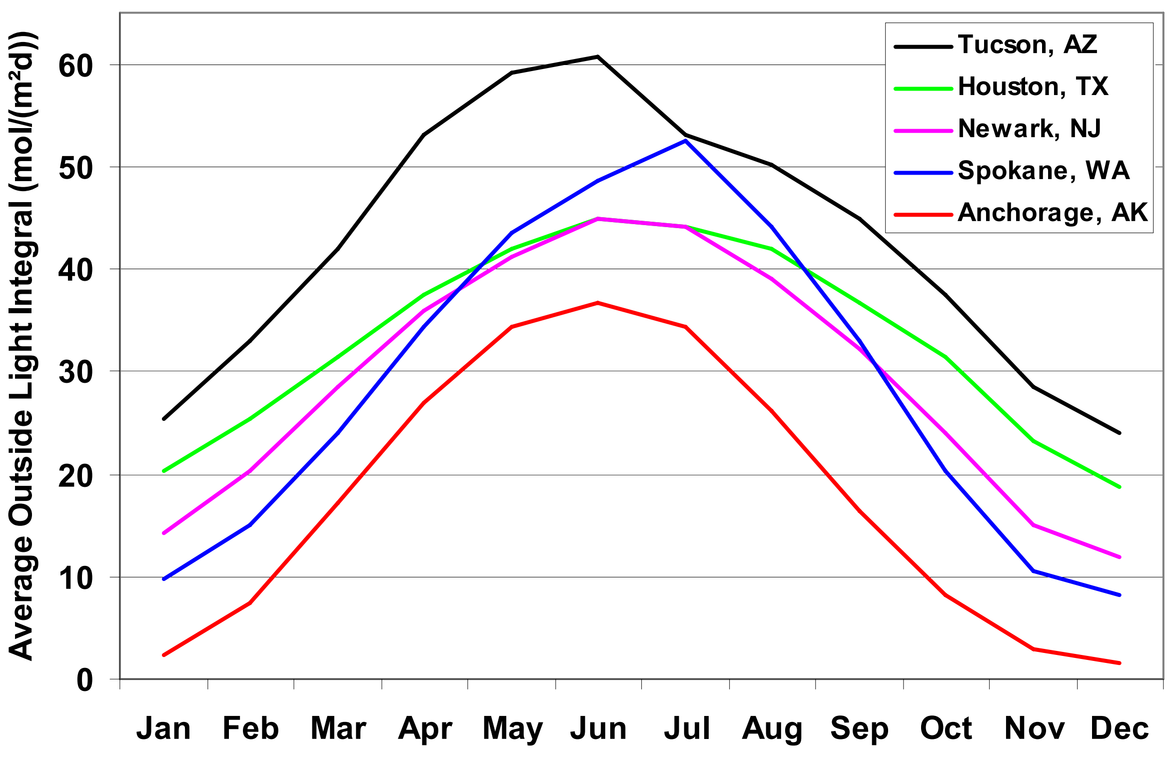

Figure 1. Monthly average light integrals for five locations in the US (1961-1990). Source: National Renewable Energy Laboratory.

Unfortunately, greenhouses transmit less than 100% of the available solar radiation due to absorption and reflection by structural elements. For typical greenhouses, on average approximately 50-70% of the outside solar radiation is available to the crops inside (Figure 2).

How many lamps do you need?

Another question a grower is faced with is how many lamps to use to improve plant production. And what light intensity should be provided by the supplemental lighting system? Most commercial supplemental lighting systems provide between 50 and 100 µmol/(m²s) (395 and 790 ft-cd, assuming the system uses HPS lamps). A one-acre greenhouse (assuming an available mounting height of 8 feet) would need approximately 383 400-watt HPS lamps for a uniform light intensity of 49 µmol/(m²s) and 786 lamps for an intensity of 100 µmol/(m²s). Additional calculations are shown in Table 1. The mounting height is the distance between the bottom of the lamp and the top of the plant canopy. Keep in mind that, although the light intensity does not change much once the lamp density is determined (Table 1), light uniformity significantly improves with increasing mounting height.

Table 1. Estimated average light intensities at the top of the plant canopy (in µmol/(m²s)) throughout a one-acre greenhouse (10 gutter-connected bays of 24' wide by 180' long) for four different mounting heights and 400-watt HPS lamps. Note 1: These average light intensities are estimates without including edge effects (i.e., a drop in light intensity towards the outside walls). Note 2: these light intensities are estimates only; always consult with a trained lighting designer for an accurate calculation of expected light intensities in greenhouses. Note 3: for HPS light, 1 µmol/(m²s) = 7.9 ft-cd.

Number of lamps per bay (per row)	Floor area/lamp (sq. feet)	Mounting height of 8 feet	Mounting height of 7 feet	Mounting height of 6 feet	Mounting height of 5 feet
38 (13-12-13)	113.7	49 µmol/(m²s)	50 µmol/(m²s)	51 µmol/(m²s)	52 µmol/(m²s)
58 (15-14-15-14)	74.5	75 µmol/(m²s)	77 µmol/(m²s)	79 µmol/(m²s)	80 µmol/(m²s)
78 (16-15-16-15-16)	55.4	100 µmol/(m²s)	103 µmol/(m²s)	105 µmol/(m²s)	107 µmol/(m²s)
123 (21-20-21-20-21-20)	35.1	149 µmol/(m²s)	154 µmol/(m²s)	158 µmol/(m²s)	162 µmol/(m²s)
158 (23-22-23-22-23-22-23)	27.3	202 µmol/(m²s)	206 µmol/(m²s)	210 µmol/(m²s)	213 µmol/(m²s)

Amount of light delivered

Research greenhouses sometimes provide light intensities of 150-200 µmol/(m²s), but these higher intensities require a lot of lamps, which would further reduce the amount of solar radiation reaching the crop. Figure 2 shows the amount of light increase that can be realized by adding supplemental lighting at three different intensities (50, 100, and 150 μmol/(m²s)), while operating the lamps for 18 hours per day during January, 18 hours per day during February, 11 hours per day during March, 2 hours per day during April, 2 hours per day during September, 12 hours per day during October, 18 hours per day during November, and 18 hours per day during December for a total of 2993 hours per year. As shown in Figure 2 for Newark, NJ, using this lighting schedule and an intensity of 150 μmol/(m²s) results in significantly smaller reduction in light integral during the darkest months of the year.

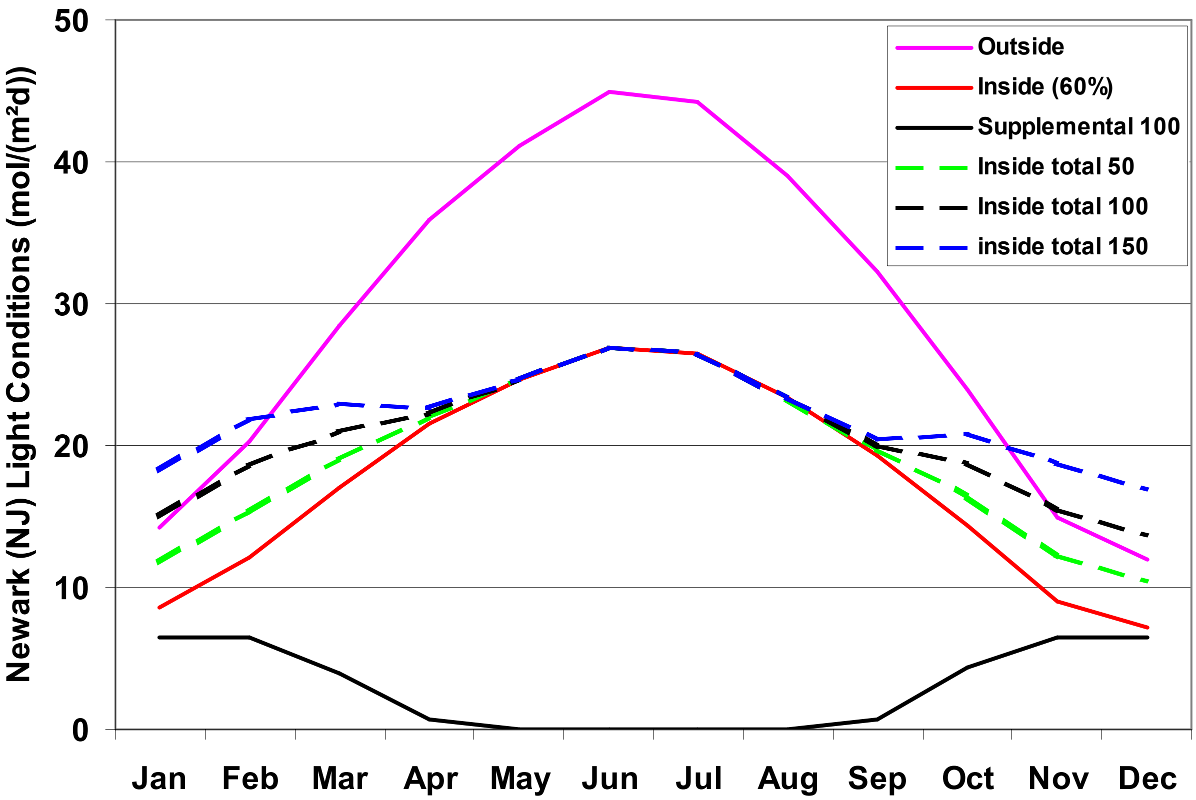

Figure 2. Monthly average outside and inside solar radiation (assuming 60% transmission) for Newark, NJ. The dashed lines indicate the inside light integrals after operating a supplemental lighting system at three different light intensities (50, 100, and 150 μmol/(m²s)) for different periods of time (see text for lighting system operating times).

Light/temperature relationship

Another way of investigating the economics of crop production (including supplemental lighting) is by studying graphs like Figure 3. This graph shows the relationship between the average temperature and the average light integral for Newark, NJ (the average temperature data shown in this figure was also retrieved from the NREL database). Figure 3 shows that spring and fall have different light and particularly different temperature conditions (significantly warmer in the fall and brighter in the spring). Thus, for this location, adding light during the late fall and early winter may be more beneficial than adding it during the spring. Of course, crop selection and scheduling will have the biggest impact on the economic value of a supplemental lighting system.

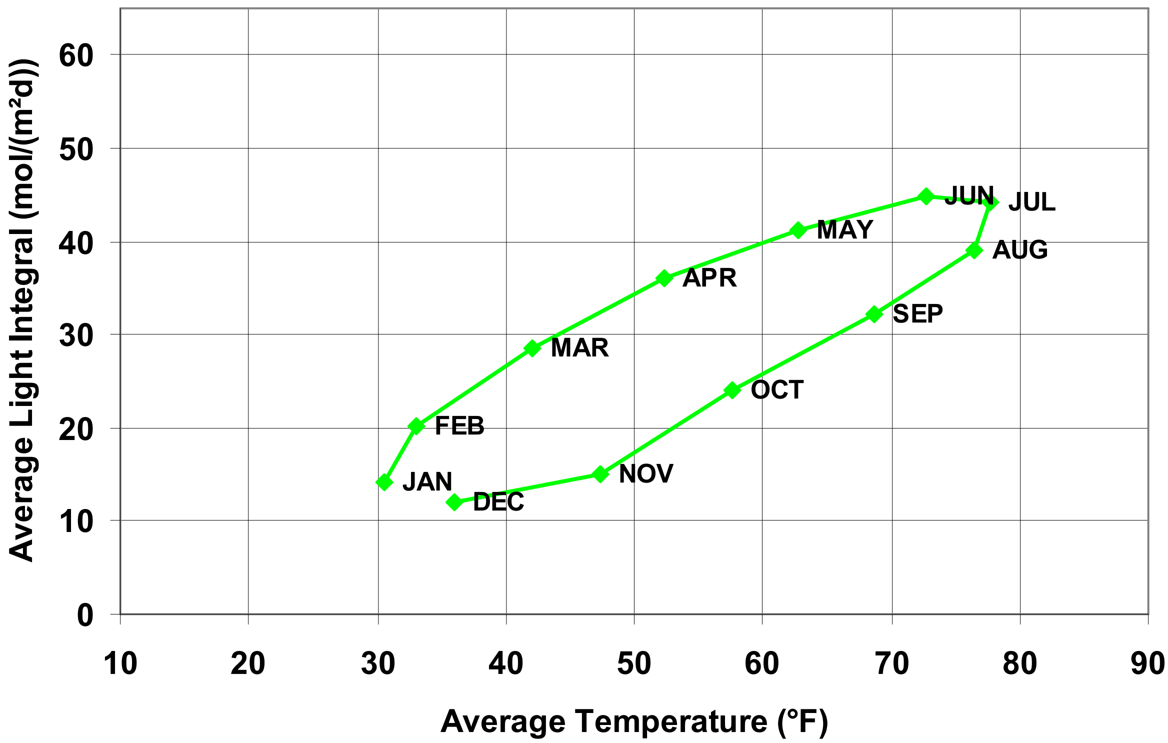

Figure 3. Average monthly temperatures versus average monthly light integrals for Newark, NJ (source: National Renewable Energy Laboratory).

Figure 4 compares the monthly average temperature and light data for the five locations shown in Figure 1. While we already knew that the growing conditions at these five locations are very different, Figure 4 quantifies these differences. If the locations shown in Figure 4 are not close to your greenhouse operation, check the NREL database for the location closest to you and use its temperature and solar radiation data to make a graph similar to Figure 3. Based on a crop's growing requirements (consult with extension agents, colleague growers, plant material suppliers, and supplemental lighting literature), graphs like Figure 3 can be used to determine (on average) how much and when supplemental lighting is needed (as well as, on average, how much heating is needed).

Keep in mind that the data the NREL database contains 30-year average values and that actual temperatures and solar radiation integrals can be significantly higher or lower for any particular time period. Most likely, designing greenhouses for extreme temperature conditions will be more important than for extreme solar radiation conditions. Nevertheless, it is important to realize that very cloudy days during the summertime will result in as little solar radiation accumulation as during many winter days. Thus, when crop timing is critical, it may be necessary to operate the supplemental lighting system on those cloudy summer days.

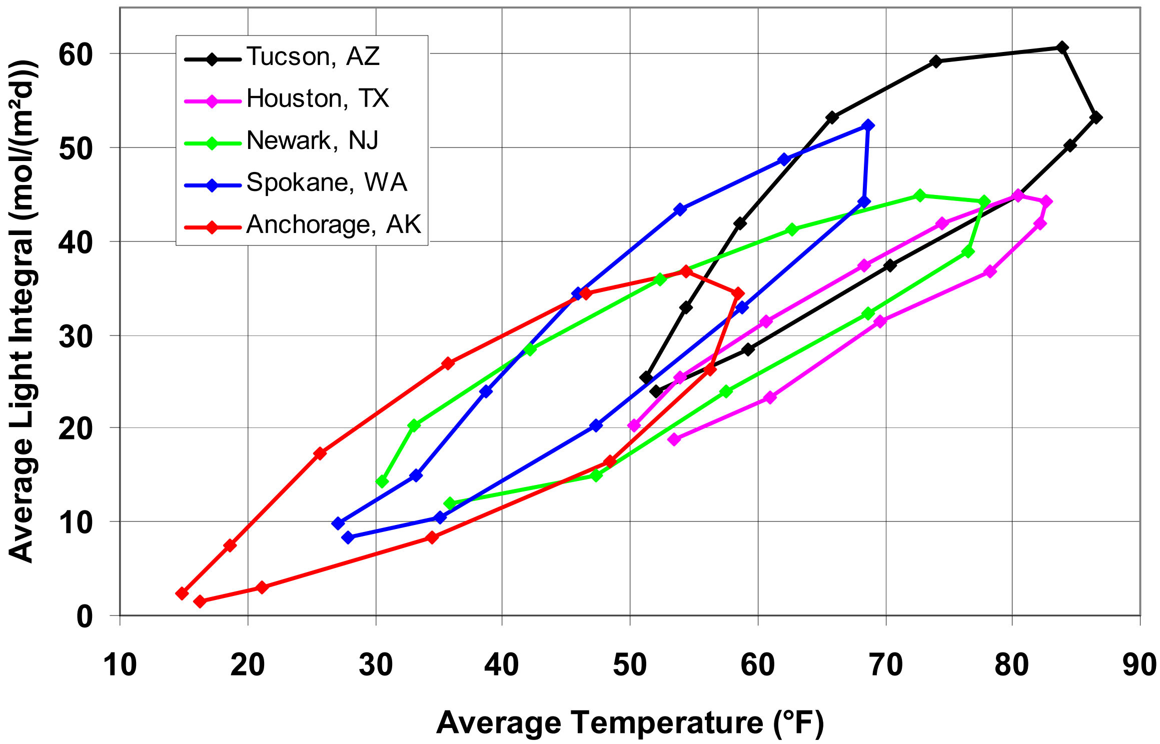

Figure 4. Average monthly temperatures versus average monthly light integrals for five locations throughout the US (source: National Renewable Energy Laboratory). The months of the year are indicated by the markers, similarly as shown in Figure 3 (time increases clock-wise).

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