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In this Issue:

Supplemental lighting for tomato production.

Considering Supplemental Lighting? Here are some data that may help you decide.

A.J. Both

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 lights, and the electricity to operate them, are not inexpensive. 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. 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)).

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).

Another question a grower is faced with is how many lamps to use to improve plant production (i.e., what light intensity should be provided by the supplemental lighting system). Most commercial supplemental lighting systems provide between 50 and 100 µmol/(m^2s) (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/(m^2s) and 786 400-watt HPS lamps for an intensity of 100 µmol/(m^2s). 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.

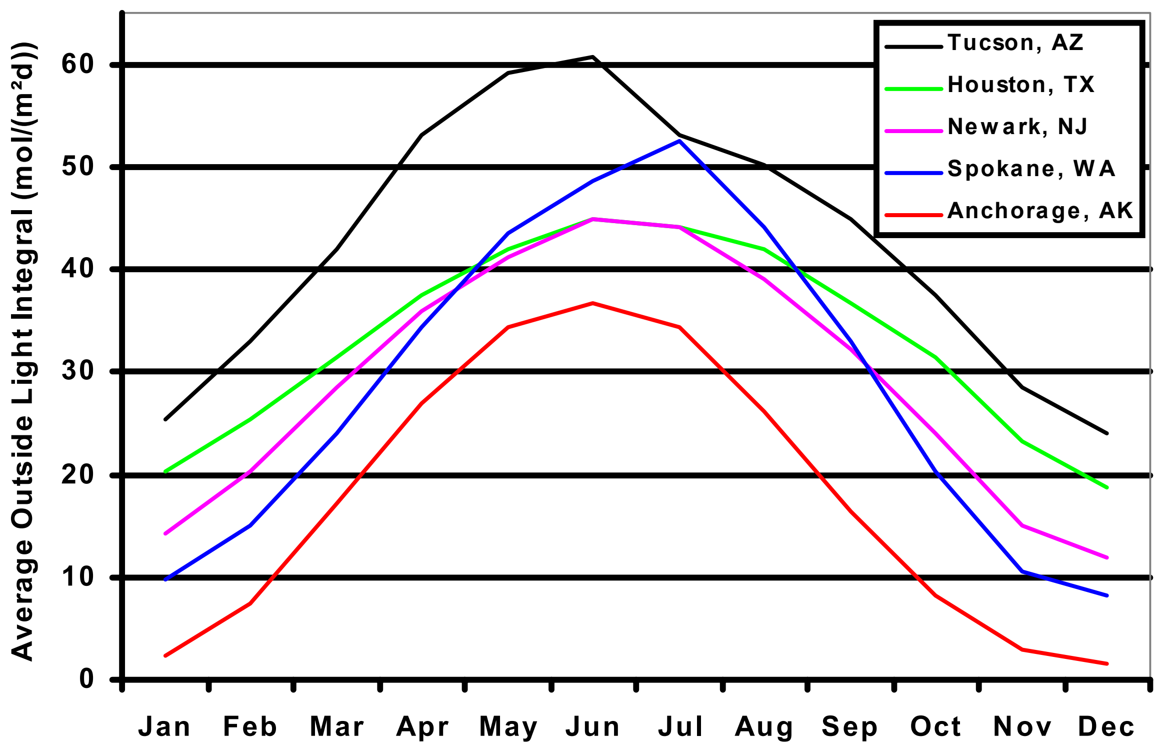

Figure 1. Monthly average light integrals for five locations in the US (1961-1990). Source: National Renewable Energy Laboratory.

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.

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)

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.

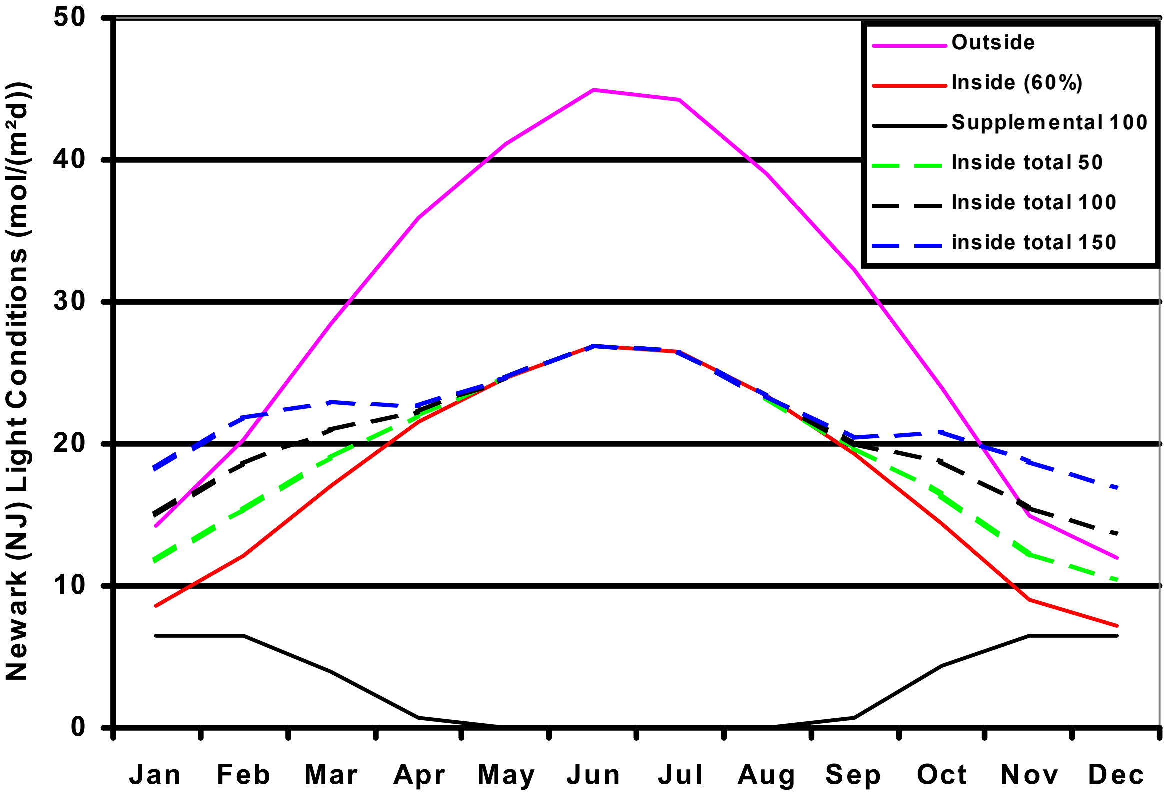

Figure 2. Monthly average outside and inside solar radiation (assuming 60% transmission) for Newark, NJ. The dashed lines indicate the inside light integrals after operating a supplemental lighting system at three different light intensities (50, 100, and 150 μmol/(m²s)) for different periods of time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

Another way of investigating the economics of crop production (including supplemental lighting) is by studying graphs like Figure 3. Such graphs show the relationship between the average temperature and the average light integral for a particular location (the average temperature data show in this figure were also retrieved from the NREL database). Figure 3, for Newark, NJ, 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.

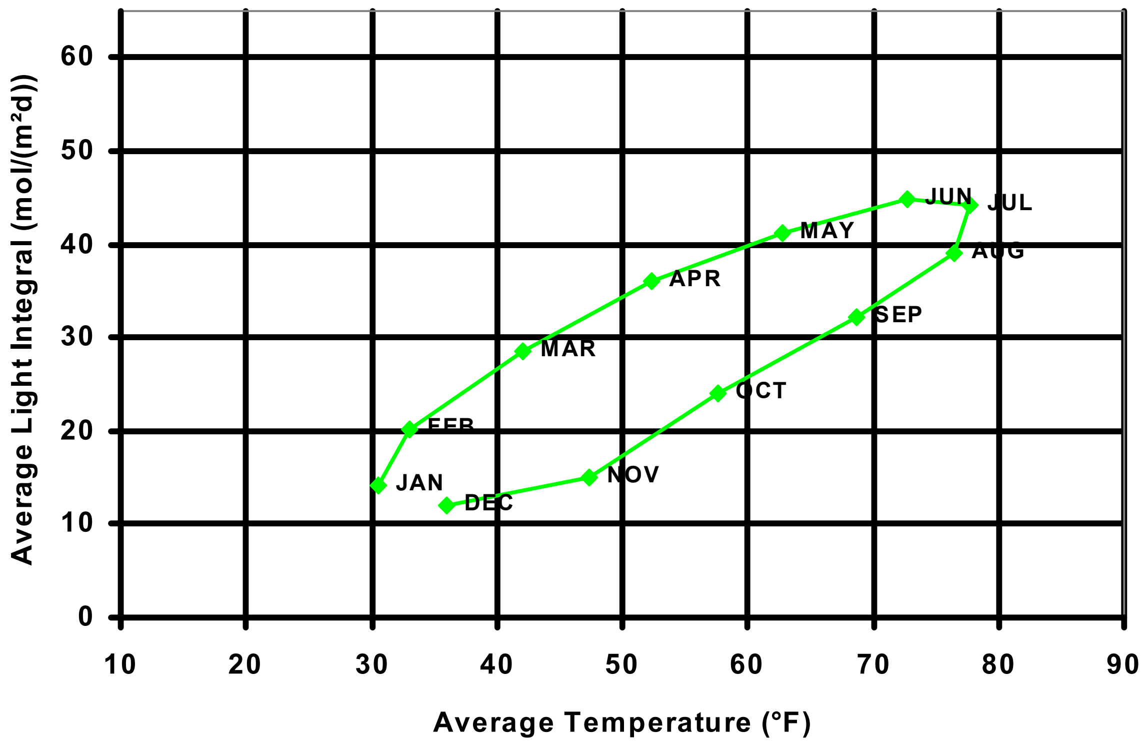

Figure 3. Average monthly temperatures versus average monthly light integrals for Newark, NJ (source: National Renewable Energy Laboratory).

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 were 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 in the NREL database are 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.

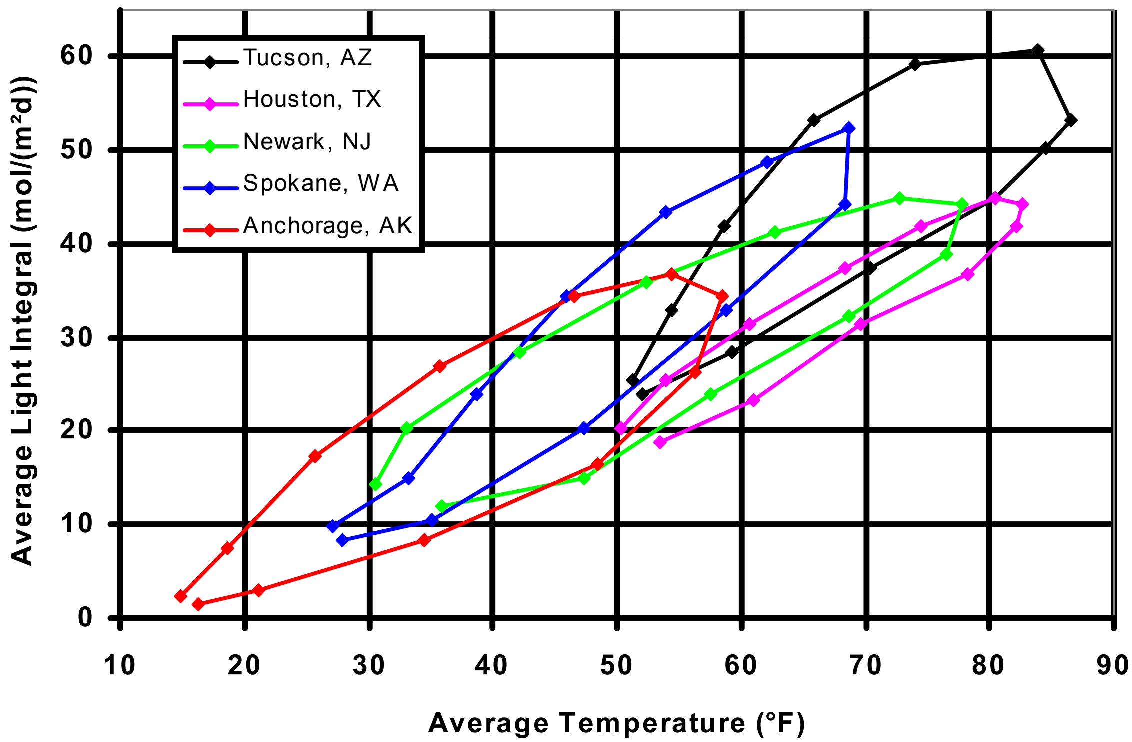

Figure 4. Average monthly temperatures versus average monthly light integrals for five locations throughout the US (source: National Renewable Energy Laboratory). The months of the year are indicated by the markers, similarly as shown in Figure 3 (time increases clock-wise).

If you are reading this article printed in black and white, you may want to visit our web site to see the graphs in color: http://aesop.rutgers.edu/~horteng (click on Newsletters).

Workshop: Renewable Energy for Homes, Farms, and Businesses
Friday, January 31, 2003 (8:00 am—4:00 pm; breakfast and lunch included)
Cumberland Regional High School
90 Silver Lake Road
Seabrook, NJ 08302
Web site: http://www.crhsd.org/directions/index.html

Agenda topics include: Today's wind, solar, and biomass technology; Financial incentives; and Opportunities in New Jersey

Please register (provide your name and contact information) by January 24, 2003:
New Jersey Department of Environmental Protection
Office of Innovative Technology and Market Development
P.O. Box 409, Trenton, NJ 08625—Fax: (609) 292-7340
For additional info, contact Athena Sarafides (609) 633-1161, NJDEP
Athena.sarafides@dep.state.nj.us

Greenhouse Engineering Workshop
February 26-27, 2003
Ohio State University
Wooster, OH 44691

The Ohio State University will host its 5th Greenhouse Engineering Workshop at the Ohio Agricultural Research and Development Center in Wooster, Ohio from 26-27 February 2003. This workshop will focus on pesticide application through a range of topics including preventative measures, effective chemistry, and efficient application technologies presented by researchers, industry leaders, and experienced growers. Hands-on sessions are designed to help participants learn from real life experience.

On Wednesday, February 26, presentations will feature topics that best serve greenhouse growers and Extension Agents, including using environmental control methods, cultural practices, and biopesticides to prevent pest problems. Effective chemistry of pesticides, growth regulators, and tank-mixing issues will be addressed. Evaluation of various sprayers on the market and application technologies will be presented.

Hands-on sessions on Thursday will provide participants opportunities to work with instructors in greenhouse environment to practice what was covered during the Wednesday sessions. Four hands-on sessions will be presented including: 1) pest diagnostics and pesticide selection, 2) water quality adjustment for effective pesticide chemistry, 3) disease pressure management decision support using a computer spread sheet, and visualization of air flow in greenhouses, and 4) evaluation of pesticide application equipment and techniques. More demonstrations and hands-on opportunities will be featured on Thursday afternoon in a commercial greenhouse using the latest spraying equipment.

For more information contact:
Dr. Peter Ling
Food, Agricultural, and Biological Engineering Department
1680 Madison Avenue, Wooster, OH 44691, USA
Phone: (330) 263-3854
E-mail: ling.23@osu.edu
Website: http://www.oardc.ohio-state.edu/ling/announce.html

Pictures from the New Jersey Poinsettia Open House, November 23, 2002. The participating wholesale growers included: Mount Laurel Gardens, Inc., Round Valley Greenhouses, Inc., Joseph Davino & Sons (picture on the left), and Holland Greenhouses, Inc. (right).

Greenhouse Cost Accounting:
A Computer Program for Making Management Decisions

A new computer program "Greenhouse Cost Accounting" could be helpful to greenhouse and nursery managers. Managers can use the software to analyze various strategies to improve the overall profitability of their businesses. This can be done by entering either hypothetical crops into the program or hypothetical changes in the current production system and comparing the results to that system. This program also could be used for student instruction in floricultural production and management or in workshops and other programs that teach greenhouse management. The program has the following goals:

* Allow greenhouse managers to allocate as many variable costs as possible from the income statement to specific crops. The program will then total the overhead costs and variable costs that cannot be allocated directly to specific crops and will allocate them to each crop on a per square-foot-week basis.
* Allow managers to determine the profit or loss of each crop.
* Provide a tool for use in financial and production management.
* Provide managers with information to reduce costs.
* Provide a planning tool to identify and eliminate unprofitable crops and increase profitable ones.
* Provide necessary cost data for pricing plants.

The Greenhouse Cost Accounting program begins by collecting information typically contained in income statements that are readily available to managers. The user then enters information on direct costs of each crop. From this input, the program allocates as many costs as possible to individual crops. The program assigns the remaining unallocated costs from the income statement to each crop on a per square-foot-week basis. The program then calculates information on costs and returns per crop, per unit (pot or flat), and per square foot for each crop, as well as an income statement showing total costs, allocated costs, and unallocated costs.

The Greenhouse Cost Account program assumes that the grower has a grasp of financial management and maintains good records.

For a copy of the software, contact Dr. Robin Brumfield: Brumfield@aesop.rutgers.edu
(732) 932-9155 ext. 253
Web site: http://aesop.rutgers.edu/~farmmgmt

Some Useful Publications/References:

NRAES 3: Energy Conservation for Commercial Greenhouses (2001 revision).
NRAES 33: Greenhouse Engineering.
NRAES 56: Water and Nutrient Management for Greenhouses.
NRAES 137: Greenhouses for Homeowners and Gardeners.
ANR UC 3311: Postharvest Technology of Horticultural Crops.

Contact information:
NRAES: http://www.nraes.org
ANR UC: http://anrcatalog.ucdavis.edu

A combination of Metal Halide (white) and High Pressure Sodium (yellow) lamps used to grow an experimental corn crop.

RUTGERS COOPERATIVE EXTENSION
COOK COLLEGE
RUTGERS, THE STATE UNIVERSITY
NEW BRUNSWICK, NJ 08901

Poinsettia trials in the open-roof greenhouse.

HORTICULTURAL ENGINEERING

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Horticultural Engineering Web Site

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Upcoming Meetings, Shows, etc.
2003

Greenhouse Engineering Short Courses:
January 13-14: Rutgers University
January 19-22: University of Arizona
February 26-27: Ohio State University

Important Dates

January 13 – 14, 2003

Greenhouse Engineering Short Course at Rutgers University

This 2-day course, coordinated by your editor, features timely topics for greenhouse operators and those interested in learning more about greenhouse engineering or perhaps thinking about getting started in the greenhouse business. Registration information is available for the Office of Continuing Professional Education at Cook College,
Phone: (732) 932-9271, or on the web: http://cook.rutgers.edu/~ocpe
It is not too early to plan to attend this program! Topics include heating, ventilation, supplemental lighting, environment control, insect screening, open-roof greenhouses, simple greenhouses (high-tunnels), planning, crop production, and more.