Commercial Greenhouse and Nursery Production

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Managing Photoperiod in the Greenhouse

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EXPERT REVIEWED

The word photoperiod combines the two Greek roots for light and duration of time — an apt description for the duration of the day that is light. In greenhouse and nursery production, photoperiod can influence many aspects of plant growth and development including dormancy, storage organ formation, and (most importantly for many greenhouse producers) flowering.

Many potted flowering and bedding plants, cut flowers, and herbaceous perennials flower in response to photoperiod. Photoperiod may also affect the onset of dormancy in perennial herbaceous and woody plants. This publication describes the most widely used and successful methods of managing the photoperiod in a greenhouse or nursery.

Plant Responses to Photoperiod

How do outdoor plants keep track of the time of the year? Temperature may seem like the obvious answer. But while climates may have seasonal patterns, temperature is not a reliable or consistent indicator of the time of year. On the other hand, seasonal changes in day length are predictable and do not change. Therefore, photoperiod is a reliable indicator of the time of year.

Plants synchronize their growth and development with different seasons to ensure they flower when the chances of pollination and subsequent seed dispersal are greatest. Similarly, day length can regulate dormancy so that winter buds may form before winter.

While we refer to photoperiod when discussing plant development, it is actually the uninterrupted period of darkness that controls plant responses to day length. The natural dark period can be extended (to create a shorter day), shortened, or interrupted by providing light (to create a longer day) to manage

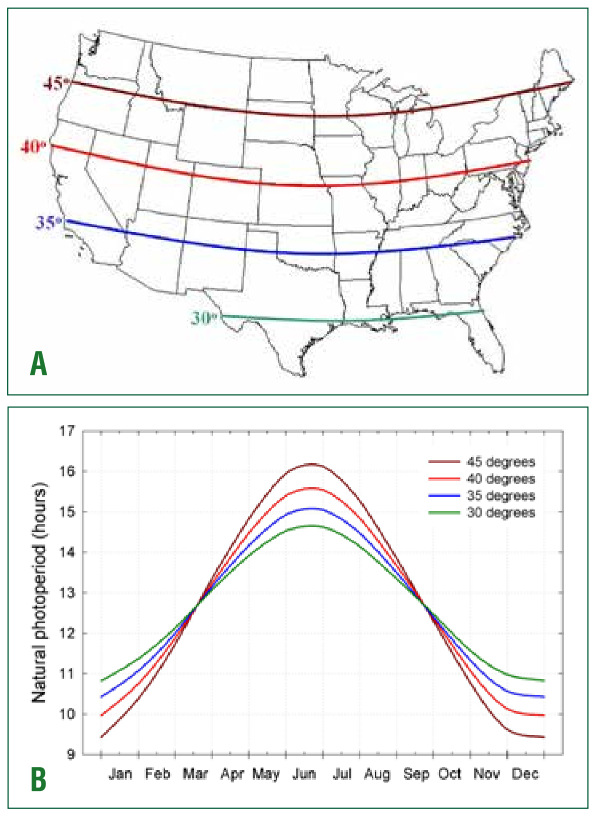

Figure 1. *The natural length of a day throughout the year varies by latitude. To determine the day length at your location, determine your approximate latitude (A), and then find the corresponding day length for the appropriate time of year (B).*

photoperiodic plant responses such as flowering. For most floriculture crops, a short day (SD) occurs when the night is at least 12 hours. For many long-day (LD) crops, a long day occurs when the night is less than 10 hours, although this varies among species.

More information about the induction of flowering using photoperiod is available in *Commerical Greenhouse and Nursery Production: Flower Induction of Annuals* (Purdue Extension publication HO-249-W), available from The Education Store (www.the-education-store.com), and on the Michigan State University Floriculture Managing Greenhouse Light page (www.flor.hrt.msu.edu/lighting).

Natural Photoperiod

Outside the greenhouse, the natural photoperiod changes throughout the year depending on the location. In the northern hemisphere, day length increases between December 21 (the shortest day) until June 21 (the longest day), after which it decreases. Seasonal fluctuation in day length becomes more dramatic as the latitude increases (Figure 1).

For example, the day length in New Orleans (30° N latitude) ranges from approximately 11 hours to a little more than 14 ½ hours. Meanwhile, the day length in Minneapolis (45° N latitude) ranges from 9 ½ to 16 hours. Because plants can perceive low light intensities, the natural (or biological) day length is approximately 30 to 40 minutes longer than the period from sunrise to sunset, depending on cloud cover, time of year, and location.

To determine your natural photoperiod, first determine your day length using the local times for sunrise and sunset. Next, add approximately 30 to 40 minutes to account for civil twilight. Using our previous examples, the natural photoperiod on December 21 would be about 11.5 hours in New Orleans and 10 hours in Minneapolis.

Creating Artificial Short Days

When the natural day length is long, there is only one way to create a short photoperiod in the greenhouse: use an opaque material that does not allow light to penetrate, which is commonly referred to as "black cloth" or "blackout cloth." You can pull black cloth over plants manually at a specified time in the afternoon (usually following the workday) to truncate the natural day length. You can also install automatic blackout curtain systems that can enclose individual benches or an entire greenhouse (Figures 2 and 3). Then, retract the cloth at a specified time in the morning to expose plants to light again.

Figure 2. *This automatic blackout cloth curtain system encloses an individual bench.*

Figure 3. *This blackout cloth curtain system encloses an entire greenhouse.*

Figure 4. *A blackout cloth made from synthetic black fabric with a reflective exterior that has been manually pulled over plants.*

Blackout cloths are generally made from synthetic black fabric (Figure 4) or plastic (Figure 5). Synthetic fabrics with reflective outer surfaces can be desirable because they reflect light and minimize heat build-up underneath the material. Black plastic

Figure 5. A blackout cloth made from plastic that has been manually pulled over a bench.

Figure 6. This boom-mounted high-intensity lamp operates during the night to provide intermittent light to the crops below.

is not widely used because it is not durable and it traps heat and condensation, which can cause the plastic to collapse on top of the plants. However, black plastic may be useful when you need to provide short days to a small number of plants (Figure 5).

Blackout cloths can lead to problems. Plants that are repeatedly exposed to high night temperatures (for example, greater than 75°F) can develop heat delay. This common physiological disorder delays flowering. Heat delay is most often reported with poinsettia and chrysanthemum.

There are a few strategies to avoid raising temperatures underneath black cloth. First, consider using a black cloth that has a reflective outer layer that reflects light (instead of just blocking it), thereby reducing radiant energy absorption from sunlight.

Second, you can alter the time for closing and retracting the black cloth. For instance, you can pull the black cloth over plants near or after sunset and retract it later in the morning. This avoids the heat of the late afternoon sun from building up under the black cloth and extends the dark period into the morning, when the greenhouse environment is cooler. Alternatively, you can open the black cloth when it is completely dark outside and release the heat. Then, at least 30 minutes before sunrise, pull the black cloth over the plants again to delay the onset of the photoperiod.

Creating Artificial Long Days

If your goal is to create an LD, you may use day-extension (DE) or night interruption (NI) photoperiodic lighting. Each method has advantages and disadvantages, but generally, they are similarly effective. Both methods require you to deliver at least 10 foot-candles (f.c.) or ~2 $\mu mol \cdot m^{-2} \cdot s^{-1}$ of light when measured at plant level.

DE lighting is the practice of delivering light to extend the length of the natural day. The length of time you light will depend on the period of darkness the plant requires and the natural day length. For example, if the natural day length is 9 hours and you desire a 14-hour photoperiod, you would operate the lights beginning at sunset for about 5 ½ hours (an extra half hour for "insurance" against sunset/dusk).

NI lighting is the practice of providing low-intensity light to plants during the middle of the night. By interrupting the dark period, the plant will not perceive a long night, but a short night (or long day) instead. NI lighting is typically delivered during the middle of night (such as from 10 p.m. to 2 a.m.), because plants are most sensitive to light at this time.

Typically, four hours of lighting is sufficient for plants that demonstrate an LD response. Some crops respond to shorter (2-3 hours) durations. Most growers provide continuous light during the NI process to ensure a long day response. However, continuous light during the NI is not absolutely necessary for plants to perceive a long day.

Cyclic (intermittent) lighting is an alternative lighting strategy that can reduce energy costs. Cyclical lighting involves using periodic lighting in the middle of the night, such as light on for 5 minutes every 20 minutes during a 4-hour period. Generally speaking, plants need to receive at least 10 f.c. (~2 $\mu mol \cdot m^{-2} \cdot s^{-1}$) for a minimum of 5 minutes every half hour. This may reduce the overall amount of energy required to elicit an LD response by up to 83 percent, although in some crops, flowering is delayed compared to plants under continuous 4-hour lighting.

Cyclic lighting may be provided several ways:

- First, use timers to turn lamps on and off, however this technique is not recommended for high-intensity discharge (HID) lamps — such as high-pressure sodium (HPS) or metal halide lamps — because these lights have a relatively long igniting period, and on/off cycles can reduce bulb life.
- Second, HPS or other HID lamps may be mounted on a boom that moves over the canopy for at least 4 hours per night (Figure 6). Little research has been conducted with this boom lighting, but growers have reported successful results. Generally, program the booms so that plants receive light at least once every 20 minutes. In addition, the suggested intensity is higher, typically at least 50 f.c., although some crops likely respond to lower light levels.
- Third, a fairly new type of HPS lamp with an oscillating reflector/luminaire provides light to plants intermittently from a stationary light source (Figure 7). This lamp casts a beam of light to crops below, and a 600-watt fixture can light approximately 1,500 square feet of greenhouse space if it can be placed high enough (at least 8 feet if possible) above crops.

Figure 7. High-pressure sodium lamps with oscillating reflectors (A) cast moving beams of light to crops below (B).

Using a low-output light source — such as an incandescent (INC), screw-in light-emitting diodes (LED), or compact fluorescent bulbs (CFLs) — or using cyclic lighting from an HID lamp, provides a negligible amount of photosynthetic light. However, when HID lamps are used to extend days, the daily light integral may increase, depending on the duration and intensity of light used. While there are benefits of supplemental or photosynthetic light, they will not be discussed here. For more information, see *Commerical Greenhouse and Nursery Production: Measuring Daily Light Integral in a Greenhouse* (Purdue Extension publication HO-238-W), and *Measuring Daily Light Integral (DLI)* (HO-238-B-W), available from The Education Store, www.the-education-store.com.

Lamp Types/Light Sources

To create NI or DE conditions, a grower has several choices. Some of these choices, plus their advantages and limitations, are:

- **Incandescent (INC) bulbs**. These are commonly used in greenhouses to provide DE and/or NI lighting (Figure 8). INC lights may be used for cyclic lighting, because the frequent on-and off will not affect bulb life or fixture longevity. INC bulbs are inexpensive and emit an effective spectrum, but they are very energy inefficient and require high power availability. Screw-in CFLs pose an attractive alternative to traditional INC lamps for DE and NI lighting. While CFLs are more energy efficient and are effective for use on many crops, their spectrum is not as effective at controlling flowering of some LD plants. CFLs are low in far-red (FR) light, which is required for rapid flowering of some LD crops like pansy and petunia. It is

Figure 8. *Incandescent bulbs are effective at providing long days, but they consume a lot of energy and are being phased out of production.*

Figure 9. *Alternating compact fluorescent bulbs with incandescent lamps can save on energy costs yet still promote flowering in a wide range of long-day plants.*

possible to alternate CFL with INC bulbs to provide the required light quality for effective photoperiodic lighting and still achieve some energy savings (Figure 9).

- **High-intensity discharge (HID) lamps**. HID lamps, such as metal halide and HPS lamps, may also be used effectively. There are several ways to use these lamps to provide DE and NI lighting. Most commonly, HPS lamps are suspended above the canopy. Another method is to mount HPS lamps on booms that move over the canopy (Figure 6). The newest development in HPS lamps is to use an oscillating reflector (Figure 7).
- **Light-emitting Diodes (LEDs)**. This technology is an emerging light source with promising plant applications, including the regulation of flowering. Their long lifespan, energy efficiency, and ability to target specific wavelengths of light make them a viable option for managing photoperiod. LEDs also provide the opportunity to adjust the ratio of red (R) and far-red (FR) light for desired plant responses. A low R/FR ratio promotes stem elongation in many plant species, which is a shade avoidance strategy plants developed from being shaded by neighboring plants. The best combination of R/FR and red/ blue is still being studied, but we do know that FR light is important in promoting flowering in LD plants. Early studies show that LEDs that emit both R and FR light are similarly effective as INC lamps. However, more research is needed on a wide variety of ornamental plants.

Conclusions

Managing the photoperiod is an important aspect of greenhouse environmental management. By understanding the natural photoperiod and the techniques used to manipulate photoperiod, you can achieve desired plant responses, such as accelerated flowering to reach target market dates more reliably.

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