Use of Lighting to Accelerate Crop Timing

By
Erik Runkle and Matthew Blanchard
A240C Plant and Soil Sciences
Department of Horticulture
Michigan State University
East Lansing, MI 48824

Light has primarily two functions during plant growth and development. First, light influences plant growth (stem thickness, rooting, branching, etc.) through the process of photosynthesis. Secondly, light influences several developmental processes, such as seed germination and flowering. During crop production, growers can manipulate the length of the day to influence flowering of crops sensitive to photoperiod, and add supplemental lighting to a crop to increase the amount of photosynthesis and thus plant growth.

Photoperiodic Lighting

Flowering in many greenhouse crops is regulated by the duration of light that a plant receives in every 24-hour period, which is referred to as *photoperiod*. For example, a 16-hour photoperiod is 16 hours of light and 8 hours of darkness. Research has shown that the duration of darkness – not the duration of light – is what controls the photoperiodic response in plants. Plants can be categorized according to how photoperiod influences flowering:

- *Long-day plants* flower when the night length is shorter than a critical duration (the photoperiod is long).
- *Short-day plants* flower when the night length is longer than a critical duration (the photoperiod is short).
- *Day-neutral plants* flower under all photoperiods and flowering is not regulated by photoperiod.

Plants that flower in response to photoperiod can be further classified as having a *facultative* or *obligate* photoperiodic response. A facultative response describes a plant that will flower faster under a particular photoperiod, but will eventually flower under any photoperiod. A plant having an obligate photoperiodic response will only flower if grown under the appropriate photoperiod. For example, black-eyed Susan (*Rudbeckia fulgida* 'Goldstrum') is an obligate long-day plant with a critical photoperiod of 13 hours following a cold treatment and 14 hours without a cold treatment (**Figure 1**). When the photoperiod is shorter than the critical photoperiod, *Rudbeckia* do not flower and plants remain as a rosette.

Knowing the photoperiodic response of different greenhouse crops can help to schedule plants in flower for specific dates and also reduce production time. For example, many bedding plants grown in spring are long-day plants and providing photoperiodic lighting can greatly accelerate time to flower and thus reduce production costs. Wave petunia is an obligate long-day plant with a critical photoperiod of 14 hours. In order to have wave petunia in flower for April 1, long days need to be provided artificially to induce flower initiation. **Table 3** and **4** provide a list of many common greenhouse

Figure 1. The effects of photoperiod on flowering of Black-eyed Susan (*Rudbeckia fulgida* 'Goldstrum'). Rudbeckia is an obligate long-day plant with a critical photoperiod of 13 hours following a cold treatment (as shown below) and 14 hours without a cold treatment. When the photoperiod is shorter than the critical photoperiod, *Rudbeckia* will remain as a rosette. Photo courtesy Erik Runkle, Michigan State University.

crops and their photoperiodic response groups.

Although a majority of bedding plants are long-day crops, there are a few species that are short-day plants, such as African marigold (*Tagetes erecta*), celosia (*Celosia plumosa*), cosmos (*Cosmos bipinnatus*), and some cultivars of zinnia (*Zinnia elegans*). Providing short days to these crops can significantly reduce time to flower. For example, 'Sonata Pink' cosmos is a facultative short-day plant, and when grown under continuous long days at 68 °F (20 °C), flowers in approximately 65 days. The same cultivar grown at the same temperature but grown under continuous short days flowers in 29 days (**Figure 2**). Research by Ryan Warner at Michigan State University has shown that for some short-day annuals, plants do not have to be grown under continuous short days to stimulate flowering. For example, providing only three weeks of short days to crops such as 'Gloria Scarlet' celosia is sufficient for flower initiation and time to flower is similar to plants grown under continuous short days.

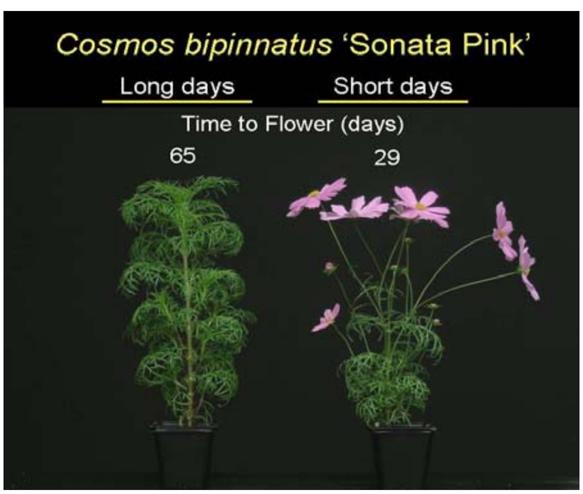

Figure 2. The effect of photoperiod on flowering in the facultative short-day plant cosmos (*Cosmos bipinnatus* 'Sonata Pink'). Plants were grown at 68 °F (20 °C) and under a 4-hour night interruption (long days) or a constant 9-h photoperiod (short days). Photo courtesy of Ryan Warner, Michigan State University.

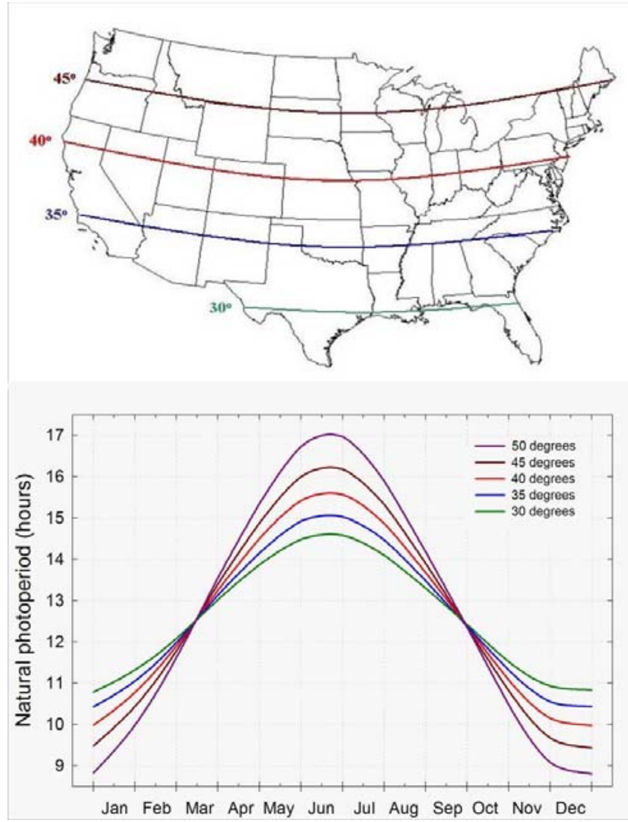

Figure 3. The natural photoperiod, which is approximately 30 minutes longer than from sunrise to sunset, depends on the time of year and geographic location. To estimate the natural photoperiod, determine the approximate latitude of your location (for example, Indianapolis, Indiana is near 40 °N), then use the corresponding curve in the bottom graph.

Manipulating Photoperiod

The natural photoperiod depends on the location and time of year. The duration of a short day or long day required to elicit a response depends on the crop grown. For example, some long-day plants flower if the photoperiod is at least 14 hours, whereas others require 15 or 16 hours of light. In general, short days exist naturally in the United States and Canada from about October 1 to March 1. Long days occur naturally from about April 15 to September 1. **Figure 3** can be used to more precisely estimate the natural photoperiod at your location. In order to grow plants under a desirable photoperiod for flower induction, it is necessary to understand the options that are available to manipulate photoperiod in the greenhouse.

Creating short days. How can we create short days when natural photoperiods are long? Short days can be created by pulling black plastic or cloth over a crop to block out the light. This can be accomplished manually by employees or with an automated blackout system. After the blackout cloth is pulled over a crop, it is important to look for small gaps where light can enter through the curtain. Some plants are able to perceive very low light intensities, so light levels should be <0.5 footcandles (<0.1 $\mu mol \cdot m^{-2} \cdot s^{-1}$) in a blackout situation. Another important consideration when pulling blackout cloth over a crop is the potential for heat accumulation under the cloth, especially when the system is closed before darkness. Exposure to high temperatures can delay flowering in some crops such as poinsettia (*Euphorbia pulcherrima*). To avoid heat accumulation under a blackout system, growers can: (1) wait until after darkness to close the blackout system and delay opening the system in the morning; (2) pull blackout cloth early in the morning before sunrise and retract later in the morning after plants have been exposed to an appropriate length of darkness; or (3) use a blackout system with an aluminum material to reflect solar radiation.

Creating long days. How can long days be created in the greenhouse when natural photoperiods are short? Long days can be created by breaking up the dark period (night-interruption lighting) or by extending the length of the day (day-extension lighting). Night-interruption lighting or "mum lighting" can be used by turning on the lights in the greenhouse for four hours continuously (e.g., 10 p.m. to 2 a.m.) to break the night into two short dark periods. Day-extension lighting can be used by turning the lights on at sunset and then turn them off after the critical photoperiod has been provided. Many different lamp types can be used for photoperiodic lighting, such as incandescent or high-pressure sodium lamps (HPS), as long as the minimum light intensity at plant level is at least 10 footcandles (2 $\mu mol \cdot m^{-2} \cdot s^{-1}$).

Another strategy to create long days in the greenhouse is to use cyclical lighting or intermittent lighting. Cyclic lighting can be provided by using incandescent lamps on a timer and setting them to turn on in the middle of the dark period for a specific cycle (e.g., 6 minutes on and 24 minutes off) for a total of four to six hours. Cyclical lighting can save on electrical costs and reduce electrical load. Cyclic lighting is only practical with incandescent lamps, because bulb life of HPS and fluorescent lamps is based on the number of times the lamp is turned on. In addition, HPS lamps require a long time to warm up. However, HPS lamps can be used for cyclic lighting by mounting them on a moving boom and programming the boom to move over the crop about every 5 to 10 minutes for at least 4 hours during the middle of the night.

A relatively new strategy to deliver cyclic lighting is to use a stationary HPS lamp that has an oscillating reflector (such as a BeamFlicker®). The reflector moves the light across the crop as it rotates, and thus provides intermittent light over the crop. This lighting strategy is very energy efficient because relatively few HPS lamps are required to create long days in the greenhouse.

Supplemental Lighting

High-intensity lamps are used in greenhouses to provide supplemental lighting to increase the rate of photosynthesis, especially during periods when the intensity of sunlight is low. Lighting to promote photosynthesis requires much higher light intensities than that for photoperiodic lighting and is usually provided by HPS or metal halide lamps.

Irradiance

Irradiance refers to the amount of light that a plant receives at a specific point in time. To measure irradiance, greenhouse growers can use hand-held light meters that report light intensity in units of footcandles or mico moles per square meter per second ($\mu mol \cdot m^{-2} \cdot s^{-1}$). Measuring light intensity in $\mu mol \cdot m^{-2} \cdot s^{-1}$ is more appropriate than measurements in footcandles because $\mu mol \cdot m^{-2} \cdot s^{-1}$ quantifies the amount of light energy used for plant photosynthesis. One $\mu mol \cdot m^{-2} \cdot s^{-1}$ of sunlight is equal to approximately 5 footcandles and 54 lux. For more information on measuring irradiance and converting between units of measurement, see chapter 1 in Fisher and Runkle, 2004 and article by Runkle, 2006.

Daily Light Integral

A limitation in reporting light quantity as an instantaneous measurement (e.g., footcandles or $\mu mol \cdot m^{-2} \cdot s^{-1}$) is that it can not be correlated to plant photosynthesis over time. Daily light integral (DLI) describes the cumulative amount of light that a plant receives in a 24-hour period and is expressed as moles per square meter per day ($mol \cdot m^{-2} \cdot d^{-1}$). During the year, DLI in a greenhouse can range from low values (5 $mol \cdot m^{-2} \cdot d^{-1}$) to high values (20 $mol \cdot m^{-2} \cdot d^{-1}$), due to factors such as the seasonal angle of the sun, cloud cover, day length, and light transmission of the greenhouse structure. For most greenhouse crops, the recommended minimum DLI for finish production is 10 to 12 $mol \cdot m^{-2} \cdot d^{-1}$. When producing crops during winter in the northern United States, the DLI in the greenhouse is often below 10 $mol \cdot m^{-2} \cdot d^{-1}$ and supplemental lighting is beneficial to maintain plant quality and crop schedules. **Figure 4** shows the average DLIs throughout the year in East Lansing, Michigan (43 °N latitude) and Phoenix, Arizona (33 °N latitude) outside and inside a typical greenhouse (65% light transmission) with or without shading. In East Lansing, Michigan, the average the DLI inside a greenhouse can range from 5 to 29 $mol \cdot m^{-2} \cdot d^{-1}$, while in Phoenix, Arizona, the average DLI can vary from 15 to 40 $mol \cdot m^{-2} \cdot d^{-1}$. It is also important to remember that the greenhouse structure, glazing material, overhead equipment, etc. can also reduce the DLI inside the greenhouse. When hanging baskets are placed overhead, the amount of light reaching the crop below can be reduced considerably and plant quality may be poor, especially in early spring (**Figure 5**).

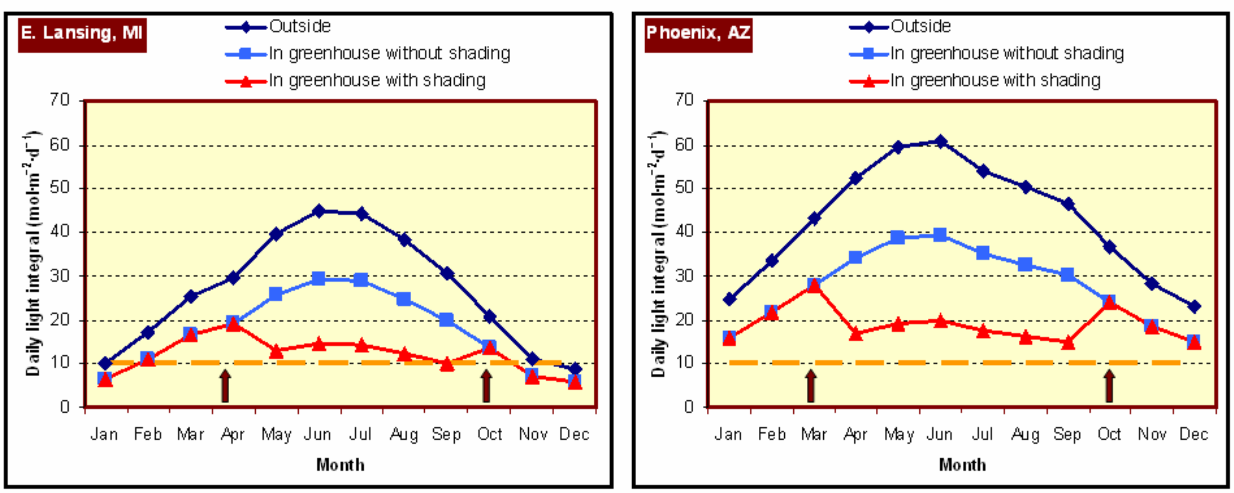

Figure 4. The average daily light integral throughout the year in East Lansing, Michigan (43 °N latitude) and Phoenix, Arizona (33 °N latitude) outside and inside a typical greenhouse (65% light transmission) with or without shading. Arrows indicate when whitewash (50% light transmission) would normally be applied or removed by the grower during the year. The dashed orange line indicates the minimum desirable daily light integral, 10 $mol \cdot m^{-2} \cdot d^{-1}$, to produce most high quality floriculture crops.

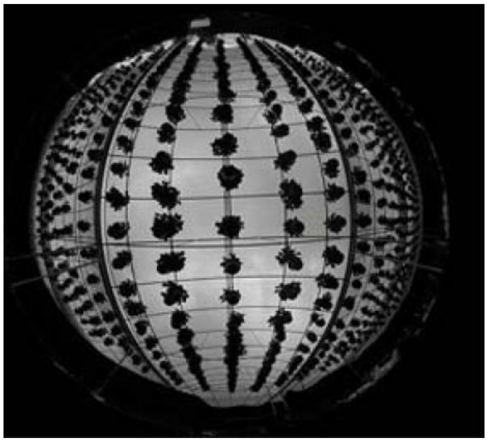

Figure 5. A "plant's eye" view from a greenhouse bench of hanging baskets overhead at a density of 1.5 baskets per square meter of greenhouse space. The hanging baskets in this example intercepted 27% of the incoming solar radiation. Photo courtesy of James Faust, Clemson University.

Adding supplemental lighting to a greenhouse is a relatively expensive investment and operational costs can be high. To minimize operational costs and save on electrical energy, consider only using supplemental lights on cloudy days when irradiance is low. Computers that control the greenhouse environment can be configured so supplemental lights only turn on when ambient light levels outside are below a minimum value, such as 300 $\mu mol \cdot m^{-2} \cdot s^{-1}$ (1,500 footcandles). Two added benefits to using HPS lamps are (1) heat is emitted from these lamps, which can save on heating fuel, and (2) the energy from the lamps can increase plant temperature, thereby accelerating crop development. For more information on determining if installing supplemental lighting is a good investment for your operation, see chapter 6 in Fisher and Runkle, 2004.

Generally, plants grown under a higher DLI will have smaller and thicker leaves, increased stem diameter, shorter internodes, increased rooting, and more lateral branches and flowers. **Figure 6** shows an example of the effect of increasing DLI on lateral branching, flower number, and flower quality of *Achillea millefolium* 'Red Velvet'. It is also important to monitor and manage DLI during seedling production and rooting of cuttings. For example, 'Vista Red' salvia (*Salvia splendens*) seedlings grown under a high DLI (16 $mol \cdot m^{-2} \cdot d^{-1}$) had increased rooting in a plug tray compared to seedlings grown under a low DLI (6 $mol \cdot m^{-2} \cdot d^{-1}$) (**Figure 7**). In addition, during vegetative propagation of petunia Tiny Tunia 'Violet Ice', as the DLI increased from 1.6 to 8.5 $mol \cdot m^{-2} \cdot d^{-1}$, rooting was accelerated by several days and

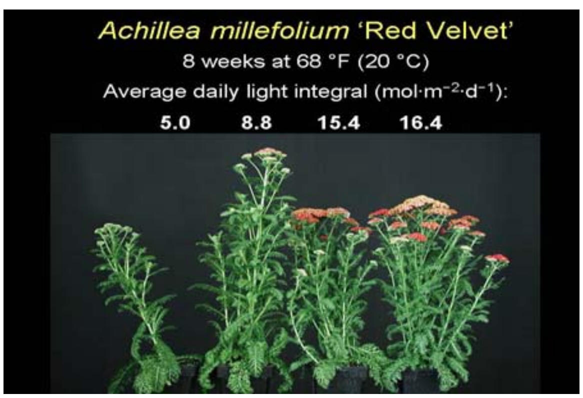

Figure 6. The effects of daily light integral (DLI) on lateral branching, number of flowers, and flower quality in *Achillea millefolium* 'Red Velvet'. Plants were grown for 8 weeks at 68 °F (20 °C) and under an average DLI of 5.0, 8.8, 15.4, or 16.4 $mol \cdot m^{-2} \cdot d^{-1}$. Photo courtesy of Beth Fausey, Michigan State University.

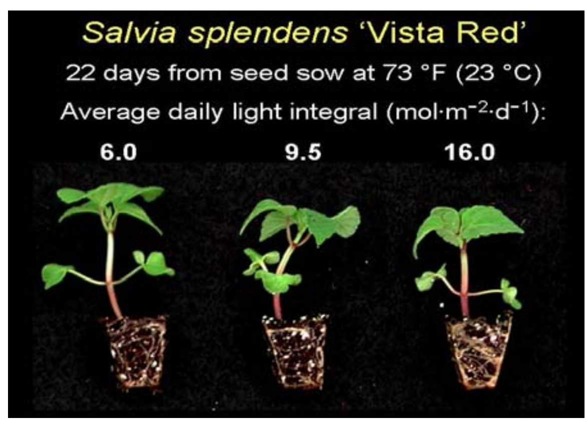

Figure 7. The effect of average daily light integral (DLI) on rooting of 'Vista Red' salvia (*Salvia splendens*). Plants were grown for 22 days after seed sow at 73 °F (23 °C) and under an average DLI of 6.0, 9.5, or 16.0 $mol \cdot m^{-2} \cdot d^{-1}$. Photo courtesy Lee Ann Moccaldi, Michigan State University.

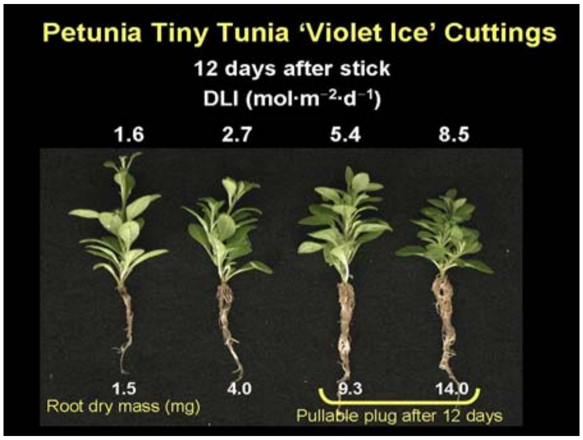

Figure 8. The effect of average daily light integral (DLI) during propagation on rooting of petunia Tiny Tunia 'Violet Ice'. Air temperature was maintained at 79 °F (26 °C) and media temperature was maintained at 75 °F (24 °C). Cuttings were rooted under an average DLI of 1.6, 2.7, 5.4, or 8.5 mol·m^{-2}·d^{-1}. Photograph was taken 12 days after cuttings were stuck. Photo courtesy of Roberto Lopez, Michigan State University.

plugs were ready for transplant earlier (**Figure 8**). For more information on managing light during propagation, see article by Lopez and Runkle, 2005.

Irradiance Response Groups

In some species, plants grown under a higher DLI will also flower faster than plants grown under a lower DLI. The acceleration of flowering under a high DLI is party due to increased plant temperature from supplemental lighting. Some species also develop and flower at a younger stage of maturity when grown under a high DLI compared to a low DLI. Research at the University of Minnesota has shown that plants can be categorized based upon how light quantity affects the flowering response:

- *Facultative irradiance response-* increasing DLI causes plants to develop fewer nodes below the first flower and thus plants flower earlier.
- *Irradiance indifferent response-* increasing DLI does not affect the number of nodes below the first flower and time to flower is not affected.

Table 5 provides a list of several bedding plants and their irradiance response groups. For more information on this topic, see articles by Erwin and colleagues, 2005a, 2005b, 2005c. Knowledge of which crops will flower earlier when provided with supplemental light can be used to reduce production time. In general, the value of supplemental lighting for many ornamental crops begins to diminish once the average DLI in the greenhouse is about 10–12 mol·m^{-2}·d^{-1}. It is important to remember that light and temperature interact to influence plant growth and development. For example, in 'Vista Red' salvia, flowering was hastened by 35 days as temperature increased from 57 to 79 °F (14 to 26 °C) and DLI increased from 6 to 26 mol·m^{-2}·d^{-1} (**Figure 9**). For more information on the interaction between temperature and light during bedding plant production, see article by Pramuk and Runkle, 2003.

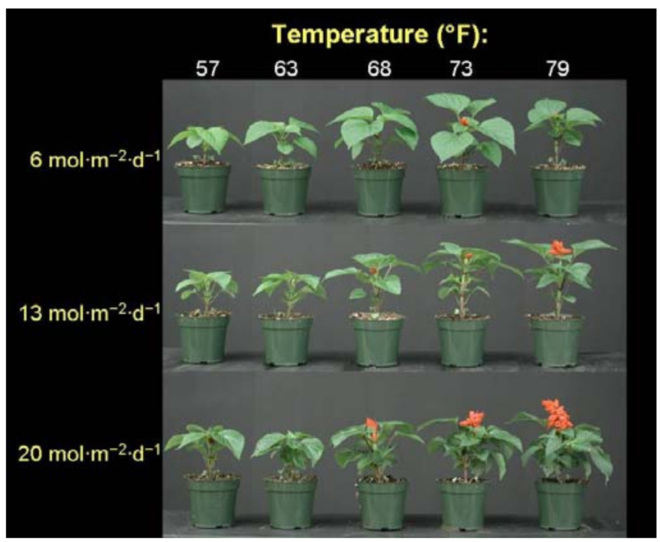

Figure 9. Growth and development of 'Vista Red' salvia (*Salvia splendens*) during the finish stage, after 19 days (from transplant of a 288-cell plug) at various temperatures from 57 to 79 °F (14 to 26 °C) and under an average daily light integral of 6, 13, or 20 mol·m^{-2}·d^{-1}. Photo courtesy of Lee Ann Moccaldi, Michigan State University.

Providing Supplemental to Plugs

During crop production, one of the most cost-effective uses of supplemental lighting is during the plug and liner stages. Adding supplemental light during this stage is especially important in the northern United States and Canada because a majority of plugs and liners are produced late in the winter and in early spring, when the natural DLI is low. Providing supplemental light to plugs has many advantages including faster growth, shorter internodes, thicker stems, increased root development, and improved quality. Plants grown under supplemental lighting can be several degrees warmer than the ambient air temperature, which can accelerate crop development. The reduced production time from using supplemental lighting during the plug stage provides the opportunity for increased revenue because more crop turns are possible.

The benefits of lighting plugs can become even more apparent after plugs are transplanted into the finish container. In some species, lighting during the plug stage can lead to earlier flowering by reducing the number of leaves formed before the first flower initiates (**Figure 10**). For example, research at Michigan State University has showed that a celosia plug grown under an average DLI of 12 mol·m^{-2}·d^{-1} flowered 8 days earlier after transplant compared to a plug grown at the same temperature but under an average DLI of 4 mol·m^{-2}·d^{-1}.

How much does is cost to use supplemental lighting on plugs and liners? Calculation estimates indicate that providing supplemental light to plugs adds very little to the cost of a plug. For example, the cost of lighting a 288-cell plug tray for three weeks with HPS lamps is approximately $0.74, which equals about one-third of a cent per plug. Thus, the installation and use of supplemental lighting on plugs can be a cost-effective strategy to shorten crop time and increase plant quality.

Figure 10. The effect of daily light integral (DLI) during the seedling stage on subsequent days to flower in five bedding plant species. After transplant, plants were grown in a common environment at 70 °F (21 °C) and under a 16-hour photoperiod. Information based on research at Michigan State University.

Average DLI (mol·m^{-2}·d^{-1})	Species				
	Celosia	Impatiens	Marigold	Pansy	Salvia
	Days to Flower				
4	43	37	21	43	28
8	39	28	18	33	25
12	35	25	17	32	21

Sources for More Information

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Tables

Table 3. Bedding plants can be categorized according to their response to photoperiod. Information based on research-based articles.

Long-day plants	**Facultative (F) or Obligate (O)**
Ageratum houstonianum (Ageratum)	F
Antirrhinum majus (Snapdragon)	F
Bracteantha bracteata (Strawflower)	O
Dianthus chinensis (Dianthus)	F
Fuchsia ×hybrida (Fuchsia)	F or O
Gazania rigens (Gazania)	O
Helianthus annus (Sunflower)	F
Lathyrus odoratus (Sweet Pea)	O
Lobelia erinus (Blue lobelia)	O
Petunia ×hybrida (Petunia, Grandiflora types)	O
Petunia ×hybrida (Wave petunia)	O
Rudbeckia spp. (Black-eyed Susan)	O
Salvia farinacea (Blue salvia)	F
Salvia splendens (Scarlet salvia)	F
Verbena ×hybrida (Verbena)	F
Viola ×wittrockiana (Pansy)	F
Short-day plants	
Celosia plumosa (Celosia)	F
Cosmos bipinnatus (Cosmos)	F
Dahlia ×hybrida (Dahlia)	F
Gomphrena globosa (Globe amaranth)	F
Ipomoea tricolor (Morning glory)	F
Lablab purpureus (Hyacinth bean)	O
Sanvitalia procumbens (Creeping zinnia)	F
Tagetes erecta (African marigold)	O
Tagetes tenuifolia (Signet marigold)	F
Day-neutral plants	
Amaranthus hybridus (Amaranthus)	
Begonia ×semperflorens-cultorum (Fibrous begonia)	
Catharanthus roseus (Vinca)	
Cleome hasslerana (Cleome)	
Convolvulus tricolor (Dwarf morning glory)	
Dianthus barbatus (Sweet William)	
Impatiens hawkeri (New Guinea impatiens)	
Impatiens walleriana (Impatiens)	
Lobularia maritima (Alyssum)	
Lycopersicon esculentum (Tomato)	
Nicotiana alata (Flowering Tobacco)	
Origanum vulgare (Oregano)	
Pelargonium ×hortorum (Geranium)	

Pelargonium peltatum (Ivy geranium)
Scabiosa columbaria (Pincushion flower)
Tagetes patula (French marigold)
Thunbergia alata (Thunbergia)

Table 4. Herbaceous perennials can be categorized according to their response to photoperiod. Information based on research-based articles.

Long-day plants	**Facultative (F) or Obligate (O)**
Achillea millefoilium (Yarrow)	O
Agastache ×'Blue Fortune' (Hyssop)	O
Asclepias tuberosa (Butterfly milkweed)	O
Astilbe chinensis (Chinese astilbe)	F
Brunnera macrophylla (Siberian bugloss)	O
Campanula carpatica (Carpathian harebell)	O
Campanula punctata (Spotted bellflower)	O
Ceratostigma plumaginoides (Leadwort)	O
Coreopsis grandiflora (Tickseed)	O
Coreopsis verticillata (Thread leaf tickseed)	O
Digitalis purpurea (Foxglove)	O
Echinacea purpurea (Purple cone flower)	F
Gaura lindheimeri (Gaura)	O
Helenium autumnale (Sneezeweed)	O
Hibiscus moscheutos (Rose mallow)	O
Hosta plantaginea (Hosta)	F
Lavandula angustifolia (English lavender)	O
Leucanthemum ×superbum (Shasta daisy)	F
Lobelia ×speciosa (Lobelia)	O
Lysimachia ciliata (Fringed loosestrife)	O
Lysimachia punctata (Yellow loosestrife)	O
Monarda didyma (Beebalm)	O
Nepeta faassenii (Catmint)	O
Oenothera speciosa (Evening primrose)	F
Pennisetum setaceum 'Rubrum' (Purple fountain grass)	F
Phlox paniculata (Garden phlox)	O
Physostegia virginiana (Obedient plant)	O
Polemonium spp. (Jacob's Ladder)	O
Rudbeckia fulgida (Black-eyed Susan)	O
Salvia ×superba (Hybrid sage)	F
Sedum spp. (Stonecrop)	O
Long-day short-day plants	
Chelone glabra (Turtlehead)	
Eupatorium rugosum (White snakeroot)	
Helianthus angustifolius 'First Light' (Perennial sunflower)	
Helianthus salicifolius 'Low Down' (Willow-leafed sunflower)	

Solidago rugosa ‘Fireworks’ (Rough goldenrod)
Day-neutral plants
Ajuga reptans (Buglewweed)
Alchemilla mollis (Lady's mantle)
Aquilegia ×hybrida (Columbine)
Armeria maritima (Sea thrift)
Campanula portenschlagiana (Dalmation bellflower)
Delphinium grandiflorum (Larkspur)
Dianthus gratianopolitanus (Cheddar pink)
Dicentra spectabilis (Bleeding heart)
Digitalis grandiflora (Foxglove)
Euphorbia epithymoides (Cushion spurge)
Geranium ‘Rozanne’ (Cranesbill)
Heuchera spp. (Coral bells)
×*Heucherella* spp. (Foamy bells)
Iberis sempervirens (Candytuft)
Lamium spp. (Spotted deadnettle)
Lychnis flos-cuculi (Ragged robin)
Nepeta faassennii ‘Snowflake’ (Catmint)
Perovskia atriplicifolia (Russian sage)
Phlox divaricata (Wild blue phlox)
Phlox subulata (Creeping phlox)
Platycodon grandiflorus (Balloon flower)
Pulmonaria spp. (Lungwort)
Salvia guaranitica (Blue anise sage)
Salvia nemorosa (Garden sage)
Scabiosa columbaria (Pincushion flower)
Tiarella spp.(Foam flower)
Veronica longifolia (Speedwell)
Veronica spicata (Spike speedwell)

Table 5. Irradiance classification of several bedding plants based on research at the University of Minnesota.

Facultative irradiance plants	Irradiance indifferent plants
Antirrhinum majus (Snapdragon)	*Ageratum houstonianum* (Ageratum)
Begonia semperflorens (Wax begonia)	*Amaranthus hybridus* (Amaranthus)
Cleome hasslerana 'Rose Queen' (Cleome)	*Ammi majus*
Convolvulus tricolor (Dwarf morning glory)	*Celosia plumosa* (Plumed celosia)
Cosmos bipinnatus 'Sensation White' (Cosmos)	*Centaurea cyanus* (Bachelor's Buttons)
Gazania rigens (Gazania)	*Cleome hasslerana* 'Rose Queen' (Cleome)
Hibiscus moscheutos (Rose mallow)	*Cosmos bipinnatus* 'Diablo' (Cosmos)
Lathyrus odoratus (Sweet Pea)	*Dianthus chinensis* (Dianthus)
Nicotiana alata (Flowering Tobacco)	*Gomphrena globosa* (Globe Amaranth)
Origanum vulgare (Oregano)	*Helianthus annus* (Sunflower)
Pelargonium ×hortorum (Geranium)	*Lobelia erinus* (Lobelia)
Petunia (Purple wave petunia)	*Salvia splendens* (Scarlet salvia)
Salvia farinacea (Blue salvia)	*Sanvitalia procumbens* (Creeping zinnia)
Viola ×wittrockiana (Pansy)	*Thunbergia alata* (Thunbergia)
	Tithonia rotundifolia (Mexican sunflower)
	Zinnia elegans (Zinnia)