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Supplemental Lighting on Bedding Plants – Making it Work for You

Ryan M.Warner
Michigan State University
Department of Horticulture
A234 Plant and Soil Sciences Bldg
East Lansing,MI 48824
Ph: 517-355-5191 x1344
Fax: 517-353-0890
warnerry@msu.edu

The dark days of winter are an excellent time to review the importance of light in plant growth and development. Light is a resource that is often in short supply during the early stages of the bedding plant production season. Providing supplemental lighting can benefit bedding plant crops in many ways. For example, controlling the day length, or photoperiod, with supplemental lighting will influence when flower induction occurs in many crops, allowing you to reduce production time and, therefore, costs. This article will discuss the benefits of both photoperiodic lighting (day length control) and photosynthetic lighting (increasing light quantity to increase plant growth) and provide you with information on how to best use supplemental lighting for your bedding plant crops.

Photoperiodic Lighting

Many bedding plant crops grown for spring sales are photoperiodic, meaning they flower in response to the length of the day and night. Growing crops under the appropriate photoperiod for early flowering can greatly reduce crop production time, thereby reducing production costs. Photoperiodic plants are classified into the following groups:

- *Long-day plants* are those that flower when the night length is shorter than a certain critical length.
- *Short-day plants* are those that flower when the night length is longer than some critical length.
- *Day neutral plants* are those that flower at a similar time under either long days or short days (i.e. flowering is not regulated by photoperiod).

The “critical” day lengths vary by crop but, generally, short-day plants will flower when the day is less than 11 hours (night length >13 hours), and long-day plants will flower when the day is longer than 14 to 16 hours (night length < 8 to 10 hours).

Within the long day and short day classifications are plants that can have either a facultative response or an obligate response. Plants with an obligate requirement for a particular photoperiod will only flower if grown under the appropriate photoperiod. Plants with a facultative response will flower earlier under the appropriate photoperiod, but will eventually flower under any photoperiod. The photoperiodic response group of many bedding plant crops is shown in Table 1.

Potted plant growers have used photoperiod manipulation for decades to control flowering of crops such as chrysanthemum. The practice of covering chrysanthemum, a short-day plant, with blackout cloth when the days are naturally long has allowed growers to produce flowering chrysanthemums at any time of the year. Photoperiod manipulation has not been common practice in the bedding plant industry. However, as we learn more about how bedding plants respond to photoperiod, it is clear that growers can greatly reduce production time of many bedding crops by manipulating the photoperiod to induce earlier flowering.

For example, *Salvia farinacea* (blue salvia), a facultative long-day plant, flowered 27 days earlier when grown under long days compared to short days! The less time a crop spends in your greenhouse, the lower your heat and labor costs to grow that crop.

Long days can be provided in the greenhouse either by extending the day with supplemental lighting, or by breaking up the dark period by turning lights on for four or more hours in the middle of the night (known as night-break, night-interruption, or “mum lighting”), traditionally from 10 p.m. to 2 a.m. Plants must generally be exposed to a minimum light intensity of 2 µmol m^{-2} s^{-1} (approximately 10 footcandles) for photoperiod control, whether as a day extension or a night-interruption.

Intermittent (cyclic) lighting can also be used during a night-interruption to provide long days. Cyclic lighting offers the opportunity to provide long-days while reducing electrical costs compared to standard nightinterruption lighting. One way to provide cyclical lighting is to have incandescent lamps on a timer, with lights being on for 6 minutes, then off for 24 minutes for 4 to 6 hours total. This strategy should not be employed with high-pressure sodium (HPS) or metal-halide lamps because these bulbs take 10 to 15 minutes to warm up to their full output, resulting in very inefficient use of electricity, and the bulb life for these bulb types decreases the more they are turned on and off.

High-pressure sodium lamps have been successfully used for cyclical lighting in two ways: mounting lamps onto an irrigation boom and having the boom move over the plants every 5 to 10 minutes, and using a stationary lamp with a rotating reflector.

Short days can be provided by pulling a blackout cloth over the crop to ensure that the day length is less than 11 hours. Although there are many more long-day plants than short-day plants among bedding plant crops, there are several important crops that are short-day plants (Table 1), including African marigold, cosmos, celosia, and *Zinnia elegans*. For short-day bedding plant crops, research at the University of Minnesota and Michigan State University has determined that three weeks of short days are generally enough to induce flowering. After flowering is induced, plants can be grown under any photoperiod (long days or short days) without a delay in flowering.

Photosynthetic Lighting

Plant growth is the result of photosynthesis, where plants use the energy from light to convert gaseous carbon dioxide into simple sugars and, ultimately, plant tissues. The rate of photosynthesis increases as light intensity increases up to a certain point (called the “light saturation point”); therefore plant growth also increases as light intensity increases. Bedding plant crops, particularly in northern regions, are typically produced during times of the year when light levels are far below the optimum for plant growth. The exceptions are pansies and other bedding crops produced during the summer for fall sales. Adding supplemental lighting from HPS lamps can greatly increase the amount of light available for plant growth during low light periods of the year. The total amount of light (photosynthetically active radiation, or PAR) received during a day is referred to as the daily light integral (DLI).

As an example, consider a plug grower starting a crop in Michigan in February. On an "average" February day, the DLI in the greenhouse will be around 8 mol $m^{-2} d^{-1}$. If the greenhouse is equipped with HPS lamps delivering 60 µmol $m^{-2} s^{-1}$ (approximately 450 footcandles; greenhouse HPS installations typically provide between 50 and 80 µmol $m^{-2} s^{-1}$ PAR) for 16 hours each day, the lamps will deliver an additional 3.45 mol $m^{-2} d^{-1}$, increasing the total DLI by almost 50 percent! The percent increase in DLI when HPS lamps are used for supplemental lighting can be much higher during cloudy days. Clearly, the relative amount of the DLI provided by HPS lamps will decline as the days of spring get longer and brighter. Using an environmental control computer to ensure that lamps are only on when the ambient light levels are low will greatly increase the efficiency of using the lamps.

The rate of development (leaf unfolding rate) of a plant is regulated by temperature. Due to the high amounts of heat given off by HPS lights, providing supplemental lighting will increase plant temperature. In general, providing 60 µmol $m^{-2} s^{-1}$ of supplemental light from HPS lamps will increase plant temperature 2 to 3°F. Therefore, plants grown under HPS lamps will develop faster than plants grown without supplemental lighting.

In addition to increasing photosynthesis, supplemental photosynthetic lighting can also greatly increase other crop quality parameters. As DLI increases, plants tend to produce more flowers (Figure 1), larger flowers, and more lateral branches. Additionally, internode elongation generally decreases as DLI increases.

Irradiance Response Groups

In addition to photoperiod effects on flowering, the total amount of light a plant is exposed to each day, or DLI, impacts the point in plant development when flowering occurs for several important bedding plant crops. Plants are classified into the following categories:

- Facultative irradiance response – increasing DLI reduces leaf number below the first flower, meaning plants flower earlier developmentally.
- Irradiance indifferent response – increasing DLI does not impact leaf number below the first flower.

When defining an irradiance response, we use the leaf number below the first flower to separate whether flowering occurred earlier under a higher DLI simply because the heat from the lamps increased the leaf unfolding rate (i.e. plants under high and low DLI flower with the same number of leaves below the first flower, but days to flower is lower for plants grown under the high DLI due to the extra heat), or because plants flowered earlier in development (i.e. with fewer leaves below the first flower). Irradiance response groups of several bedding plant species are listed in Table 2.

Lighting during the Plug Stage

There are several advantages to lighting during the young plant stage. The increased photosynthesis under supplemental lighting will produce plugs with thick, strong stems. Supplemental lighting also greatly increases root growth (Figure 2), leading to a more "pullable" plug for transplanting. The extra heat coming from the lamps, combined with the extra light available for shoot and root growth, often reduces plug production time, allowing you to produce more crop cycles per season. Lighting during the plug stage can also result in significant "carryover" effects for finished crops. When supplemental lighting is used to extend the day length, flowering of long-day plants is promoted, reducing production time for the finisher.

Growing Under HPS Lamps May Change Your Cultural Practices

Due to the extra light and heat given off by HPS lamps, your production practices will have to be altered accordingly. For example, plant stomata (the pores on the leaves that allow carbon dioxide to move into the plant for photosynthesis and water vapor to move out of the plant through transpiration) will be more widely open under higher irradiance. Therefore, plants will transpire more and your irrigation schedule will have to be adjusted to provide more frequent watering.

Plants generally grow shorter under higher irradiance. This will require you to adjust your plant growth regulator (PGR) practices. Plants grown under supplemental lighting will generally require fewer PGR applications, or applications of a lower rate of chemical compared to crops grown without supplemental lighting.

Supplemental lighting will also accelerate flowering on many crops. This is a result of the increase in temperature for plants grown under supplemental lighting, resulting in a higher leaf unfolding rate, and promotion of flowering in long-day plants by extending the day length with supplemental lighting. Therefore, your production schedules will have to be adjusted as crops will finish earlier. Plug producers can take advantage of this to get more "turns" through the greenhouse each season, making the investment in supplemental lighting economical.

Is Supplemental Lighting Right for You?

All growers should use photoperiodic lighting during production of spring bedding plant crops. The installation and operation costs are relatively low, and production time of many crops can be reduced by several weeks, substantially reducing production costs. Remember, the less time your crops spend in the greenhouse, the less you have to heat them.

Adding HPS lights is a significantly larger financial investment. For a positive return on the investment, you either need to produce and sell more product, or get a higher price for a premium quality product. Plug growers should strongly consider investing in HPS supplemental lighting, as supplemental lighting can increase the number of plug crops that can be produced, and offers the opportunity to get a higher price for plugs that will flower faster in the finishing environment. Similarly, yield of vegetative cuttings often increases as DLI increases. Growers that produce plugs for finishing "inhouse" should consider installing HPS lamps in the greenhouse sections used for producing the plugs, then using those sections to finish crops with a facultative irradiance response.

Table 1. Photoperiodic response groups for numerous annual bedding plants.

Obligate Long-Day Plants	
Ammi majus	Asperula
Bachelor's Buttons (*Centaurea*)	Catananche
China Aster (*Callistephus*)	Dill
Flax (*Linum*)	*Fuchsia x hybrida*
Gazania	Ipomopsis
Lavatera	Legousia
Leptosiphon	Limnanthes
Lobelia	Love-In-The-Mist (*Nigella*)
Monkey Flower (*Mimulus*)	Nierembergia
Primrose (*Oenothera*)	Petunia ('Purple Wave')
Platystemon	Rudbeckia
Strawflower	Sweet Pea (Lathyrus)
Tuberous begonia (*Begonia tuberhybrida*)	
Facultative Long-Day Plants	
African Daisy (*Dimorphothica*)	Ageratum
Basil	Calendula
Collinsia	*Dianthus chinensis*
Linaria	Mexican sunflower (*Tithonia*)
Pansy (*Viola*)	Petunia (Grandiflora types)
Phacelia	Reseda
Salpiglossus	Salvia
Snapdragon	Statice
Sunflower	
Obligate Short-Day Plants	
Mina Vine	Hyacinth Bean
African Marigold (*Tagetes erecta*)	
Facultative Short-Day Plants	
Celosia	Cosmos
Creeping Zinnia (*Sanvitalia*)	Globe amaranth (*Gomphrena*)
Hiemelis begonia	Moonflower (*Ipomea*)
Morning Glory (*Pharbitis*)	Signet marigold (*Tagetes tenuifolia*)
Zinnia (*Zinnia elegans*)	
Day-Neutral Plants	
Amaranthus	*Asclepias curassavica*
Balsam (*Impatiens balsamina*)	*Begonia semperflorens* (Wax begonia)
Carpanthea	Centranthus
Cleome	Cobea
Dianthus barbatus	French marigold (*Tagetes patula*)
Geranium	Impatiens
Nemophila	New Guinea impatiens
Oxypetalum	Stock
Verbascum	*Zinnia angustifolia*

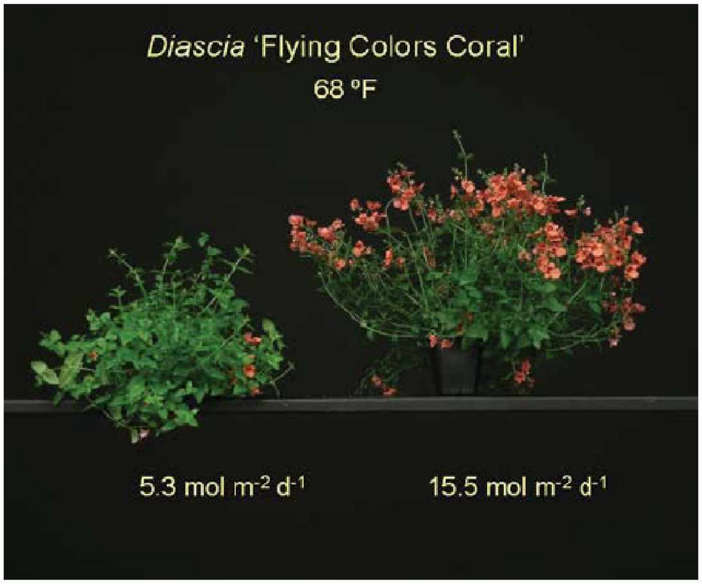

***Figure 1**. Increasing daily light integral from 5.3 mol m² d¹ (a typical greenhouse value in Lansing, MI in January) to 15.5 mol m² d¹ (a typical value in April) greatly increases flower number of Diascia 'Flying Colors Coral'. Both plants were grown at constant 68°F.*

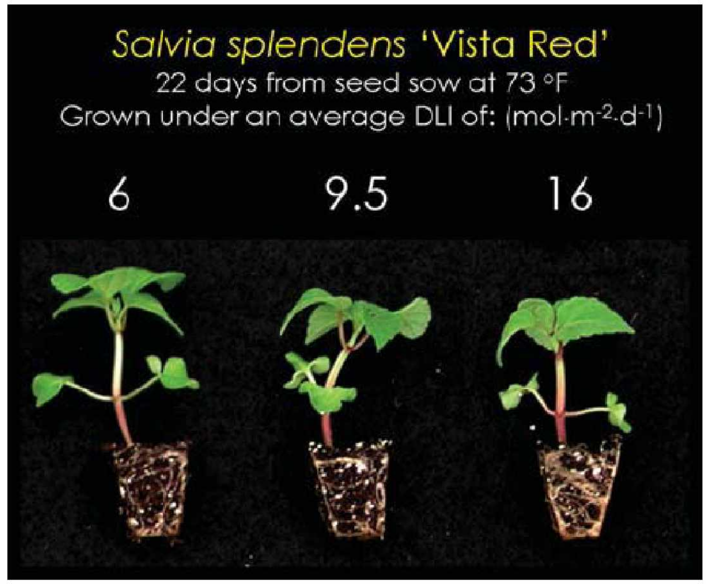

***Figure 2**. Salvia splendens 'Vista Red' root growth is much greater at a daily light integral or 16 mol m² d¹ compared to 6 or 9.5 mol m² d¹, resulting in reduced plug production time. (Photo courtesy of Erik Runkle, Michigan State University).*

Table 2. Irradiance response groups of several annual bedding plants.	
Facultative Irradiance Response	
Blue Salvia	Catananche
Centranthus	Cleome
Cosmos	Cyclamen
Dwarf Morning Glory (*Convulvulus*)	English Primrose
Flowering Tobacco (*Nicotiana*)	Gazania
Lavatera	Love-In-The-Mist (*Nigella*)
Limnanthes	Nemophila
Pansy	Petunia 'Purple Wave'
Poppy	Silene
Snapdragon	Sweet Pea
Wax Begonia	
Irradiance Indifferent	
Ageratum	Amaranthus
Calendula	Cobea
Dianthus	Dimorphothica
Gomphrena	Ipomopsis
Lobelia	Mimulus
Mina Vine	Sanvitalia
Statice	Stock
Thunbergia	Verbascum
Zinnia	