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Flower Induction of Annuals

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EXPERT REVIEWED

Annual bedding plants are one of the most valuable sectors of the U.S. commercial floriculture industry because they provide instant color for consumers. The vast majority of these plants are sold during a narrow market window of four to six weeks during the spring.

***Figure 1**. These seedlings have a short juvenile period. They can perceive photoperiod after just one pair of true leaves have emerged. Photo by Roberto G. Lopez, Purdue University.*

If these plants have even just a few flowers, customers get an idea of what the plant looks like in full bloom, which can increase impulse purchases. However, to be able to deliver to retailers annual bedding plants that are in flower, producers must understand their flowering requirements.

There are several factors involved with inducing annuals to flower, but growers must focus on:

- Juvenility
- Photoperiod (day length)
- Light intensity
- Temperature

This publication examines these factors and provides information to help you successfully control flower induction of your annual bedding plants.

Juvenility

Juvenile plants are unable to form flowers even if they receive flower-inducing signals such as changes in day length or temperature. Plants must pass through this juvenile period and become mature before they can respond to inductive cues and flower.

The length of the juvenile period varies widely among plant species and can be measured by a physical factor such as leaf or node number (for plants with short juvenile periods), or by time such as years (for long juvenile periods). For example, some trees have juvenile periods of more than 30 years, while some annuals can perceive inductive photoperiods beginning when only one pair of leaves has unfolded (Figure 1).

How does juvenility affect the flowering of annuals? Many bedding plants are propagated by seeds and producers commonly receive seedlings in plug trays. When you order plugs it is not the size of the plug itself that determines juvenility, but the developmental age of the seedling.

Figure 2. *Cosmos is a short-day plant. The plants on the left were grown under a long-day photoperiod created by night interruption lighting. The plants on the right were grown on a short-day photoperiod created by black cloth. Photo provided by Ryan Warner, Michigan State University.*

For example, a seedling grown in a 512-cell plug tray is typically sold at an earlier developmental age than a seedling in a 128-plug tray. This is because the seedlings required fewer leaves (less plant development) to fill in the 512-cell tray than the seedlings in the 128-cell tray. Consequently, the seedlings in the 128-cell tray are more mature than seedlings in the 512-cell tray. Once transplanted, seedlings from the 512-cell tray may outgrow the juvenile stage and flower induction may take place.

Although many bedding plants are propagated from seed, popularity is growing for varieties and species that are propagated by cuttings. Juvenility does not apply to vegetatively propagated crops. Cuttings harvested from stock plant tissue are already mature and capable of responding to inductive conditions immediately.

Vegetative cuttings are produced by maintaining stock plants under noninductive photoperiods, pinching terminal buds, and applying ethephon (Florel®). However, since cuttings come from mature (non-juvenile) mother plants, they are capable of being induced to flower.

Photoperiod (Day Length)

Flowering responses are described based on the response to the length of the day (even though research demonstrates that the real inductive signal is the length of night).

As a grower, you should be familiar with several concepts related to photoperiodic flower induction, including: photoperiodic response groups, critical day length, and inductive cycle number.

Photoperiodic Response Groups

Plants are divided into three main categories (photoperiodic response groups) based on when they flower:

- **Short-day plants (SDP)**, which flower when the day length is at or shorter than a certain time. Technically, because plants are actually responding to night length, short-day plants flower in response to a long night length (Figure 2).
- **Long-day plants (LDP)**, which flower when the day length is at or longer than a certain time.
- **Day-neutral plants (DNP)**, which flower regardless of the day length.

Furthermore, LDP and SDP responses may be further classified as either obligate or facultative.

Plants with an obligate photoperiod response *must* be exposed to short or long photoperiods to flower or will remain vegetative.

Alternatively, plants with a facultative photoperiod response will flower more *quickly* when exposed to inductive long days (LD) or short days (SD) — flowering will eventually occur regardless of day length.

Table 1 lists the photoperiodic response groups of many common bedding plant species.

Critical Day Length

How do you know how "long" or "short" a day needs to be to induce flowering?

The specific day length that a plant requires to flower can be called the critical daylength (CDL). Broadly defined, CDL is the length of the photoperiod at which flowering occurs.

CDL can vary among photoperiodic species. Florist (potted) chrysanthemums (an SDP) have a CDL of around 14 hours, and flowering occurs when the photoperiod is 14 hours or shorter. In the case of garden chrysanthemums, some cultivars flower earlier in the fall (early-season chrysanthemums) than others (late-season chrysanthemums). Early-season chrysanthemums have longer CDLs, which is why they flower earlier in the summer than their late-season counterparts.

One way to create SD photoperiods is to truncate the day length by pulling blackcloth over plants in the late afternoon or evening and retracting it in the morning to create the desired photoperiod.

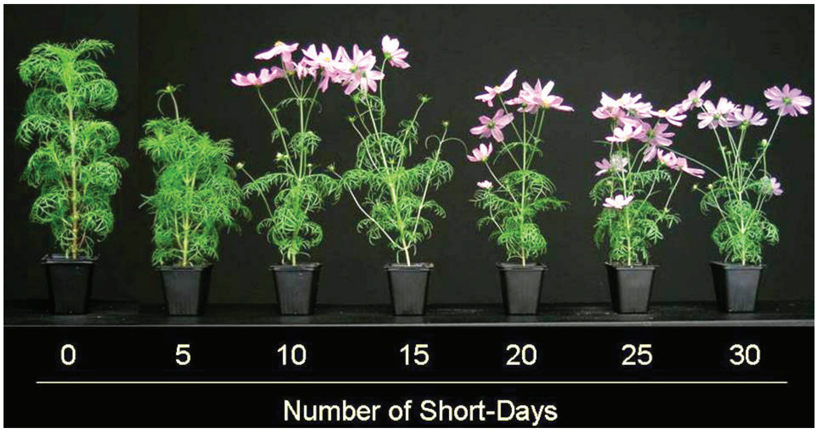

Figure 3. The cosmos shown here received 0, 5, 10, 15, 20, 25, or 30 inductive short days before being placed under noninductive long days. Photo provided by Ryan Warner, Michigan State University.

A way to create LD photoperiods is to use day-extension (DE) or night-interruption (NI) lighting. With DE lighting, you turn on a light source (such as high-pressure sodium (HPS) or incandescent lamps) before the sun sets, and keep them on until you achieve the desired day length. With NI lighting, you use some type of light to “interrupt” the dark period in the middle of the night — traditionally by using incandescent lamps to provide ~2 $\mu mol \cdot m^{-2} \cdot s^{-1}$ (10 foot-candles) from 10 p.m. to 2 a.m. By interrupting the dark period, plants perceive a short night length and, therefore, an LD photoperiod.

Inductive Cycle Number

When you are inducing plants to flower, each 24-hour period is referred to as an inductive cycle. Plants must be exposed to a minimum number of inductive cycles to induce a flowering response. The critical cycle number (CCN) is the minimum number of inductive cycles a plant must experience to ensure flowering will occur even if plants are placed under noninductive photoperiods (Figure 3).

You can regulate plant height by limiting how much exposure LD annuals have to inductive photoperiods by using a technique called limited inductive photoperiod treatment (LIP). To do this, expose plants to LD photoperiods for the CCN, and then expose them to SD photoperiods. The result is plants that are in flower, but have limited stem elongation.

However, using LIP is not ideal for every crop. For example, ‘Classic Liberty Bronze’ snapdragons (*Antirrhinum majus*) grown under continuous LD flowered quicker than plants exposed to less than 30 LDs.

To maximize your success with photoperiodic annuals, it is best to try and familiarize yourself with the photoperiodic response group, CDL, and CCN requirements for the annuals you are producing.

Light Intensity

The total amount of photosynthetic light a plant receives throughout the day — called the daily light integral (DLI) — can affect plant attributes, including crop timing and quality.

DLI and Growth

The time to flower decreases under light limiting conditions when DLI is limiting (< 12 $mol \cdot m^{-2} \cdot d^{-1}$), as the DLI increases overall plant mass and number of flowers and branches increase, and in certain crops. The increased crop quality is due to increased plant photosynthesis in response to the increased DLI. It may also be due to changes in plant habit. A plant receiving high light may develop more lateral branches and thus have more leaves to capture light. Additionally, crop time is usually reduced when supplemental lights such as HPS lamps are used. This is because the energy from the lamps increases plant temperature, thus increasing plant developmental rates.

More information about DLI is available in *Commercial Greenhouse and Nursery Production: Measuring Daily Light Integral in a Greenhouse* (Purdue Extension publication HO-238-W), available from the Purdue Extension Education Store, www.the-education-store.com.

Irradiance Response

DLI affects overall crop quality and production time, but it has other effects, too. As DLI increases, the amount of time a plant needs to flower may be reduced. That’s because the number of leaves unfolded below the first flower have been reduced (in other words, increased DLI may induce flowering at an earlier developmental state than normal). This is called a facultative irradiance (FI) response.

Alternatively, an irradiance indifferent (II) response is when increasing DLI has no effect on the number of leaves below the first flower or on time to flower.

For example, research has shown that when 'Rose Queen' cleome (*Cleome hasslerana*) received 1,145 foot candles (150 $\mu mol \cdot m^{-2} \cdot d^{-1}$) of supplemental light, the number of leaves below the first flower decreased by eight, and time to flowering decreased by 37 days compared to plants grown under ambient light — these plants demonstrated an FI response. When desert bells (*Phacelia campanularia*) received the same supplemental light, leaf number and time to flowering were the same as plants under ambient light — these plants demonstrated an II response.

Table 1 lists the irradiance response groups of many common bedding plant species.

Temperature

To produce the highest quality flowering plants, it is important to understand how each plant responds to temperature. In addition to the general effect of the average daily temperature (ADT) on plant development, annuals may be sensitive to temperature extremes.

Temperature and Development

A plant's development rate is primarily a function of the average daily greenhouse temperature. Generally, within a range of ADT from 45ºF to 85ºF production time increases or decreases as the ADT decreases or increases, respectively.

Temperature Sensitivity

High night temperatures can delay flowering, a disorder called "heat delay." This disorder is common with potted crops such as poinsettia (*Euphorbia pulcherrima*) and kalanchoe (*Kalanchoe blossfeldiana*), but it can affect some annuals including gomphrena (*Gomphrena globosa*) and New Guinea impatiens (*Impatiens hawkeri*).

Lastly, some annuals are sensitive to the ADT, regardless of the nighttime or daytime temperatures. This response is common in zonal geraniums (*Pelargonium* × *hortorum*), which produce fewer flowers as the ADT increases from 50°F to 86°F.

Table 1 outlines ideal production temperatures for many common bedding plant species.

Bringing It All Together

So how can you put together all of this information to help you get your annuals in flower on time?

First, sit down and put together a production schedule. Start with your target sales date. Next, identify if the species you are scheduling has a photoperiodic response.

Let's say you want a crop in flower for Week 22, it is an SDP, and it flowers about five weeks after the start of SD. To get plants flowering by the target sales date, you should start SDs during Week 17.

Alternatively, if you are trying to bulk up plants so they will fill in larger containers, you don't want to grow them under inductive photoperiods that result in flowering too soon after planting.

Alternatively, consider a seed-propagated petunia (*Petunia* ×*hybrida*) crop in 5-inch pots. Since most seed petunias are LDPs, you'll want to keep plants under SD conditions for a few weeks after transplanting to promote vegetative growth and inhibit flowering. After the plants reach a certain size, you can place them under LD conditions to promote flowering.

If you are unsure about the photoperiodic or irradiance responses of an annual you are growing, try some small-scale tests to learn about the responses. For example, put a few plants under blackcloth and a few under NI lighting and see how they respond. Similarly, grow some plants with and without supplemental light to see how they respond to the differences in light.

Table 1. Photoperiod responses, irradiance responses, and temperature groups for numerous bedding and perennial plants.

Scientific Name	Common Name	Photoperiod Response[1]	Irradiance Response[2]	Temperature Group[3]
Abutilon × *hybridum*	flowering maple	DNP	—	—
Achimines hybrids	achimenes	DNP	—	—
Acroclinium roseum	strawflower	OLDP	II	—
Ageratum houstonianum	flossflower	FLDP	—	2
A. houstonianum 'Blue Danube'		FLDP	II	2
A. houstonianum 'Tall Blue Horizon'		FLDP	—	2
Alcea rosea	hollyhock	LDP	—	2
Amaranthus hybridus 'Pygmy Torch'	smooth amaranth	DNP	II	2
Ammi majus	bishop's weed	OLDP	II	1-2
Angelonia angustifolia	summer snapdragon	DNP	—	—
Anethum graveolens	dill	OLDP	II	1
A. graveolens 'Mammoth'		OLDP	II	1
Anisodontea × *hypomandarum*	cape mallow	FLDP	—	—
Antirrhinum majus	snapdragon	FLDP	FI	1-2
A. majus 'Floral Showers Crimson'		FLDP	—	1-2
A. majus 'Spring Giants'		FLDP	—	1-2
Argyranthemum frutescens	marguerite daisy	DNP		—
Asclepias curassavica	Mexican butterfly weed	DNP	FI	2
A. tuberosa	butterfly weed	OLDP	—	2
Asperula arvensis 'Blue Mist'	blue woodruff	OLDP	II	—
Begonia × *hiemalis*	rieger begonia	O/FSDP	—	2
B. tuberhybrida	tuberous begonia	OLDP	—	2
B. semperflorens	wax begonia	DNP	FI	2
Bougainvillea spp.	paper flower	FSDP	FI	—
Bracteantha bracteata	strawflower	DNP	—	—
Calceolaria herbeohybrida	pocketbook plant	FLDP	—	—
Calendula officinalis	pot marigold	O/FLDP	—	1
C. officinalis 'Calypso Orange'		FLDP	II	1
Calibrachoa 'Colorburst Violet'	million bells	FLDP	—	—
C. 'Liricashowers Rose'		FLDP	—	—
Callistephus chinensis	China aster	FLDP	—	1
Capsicum annuum	pepper	DNP	—	2
Carpanthea pomeridiana 'Golden Carpet'	golden carpet	DNP	II	—
Catanache caerulea 'Blue'	Cupid's dart	OLDP	FI	1-2
Catharanthus roseus	vinca	DNP	—	3
Celosia argentea	cockscomb	FSDP	—	2
C. plumosa 'Flamingo Feather Purple'		OSDP	II	2

Table 1. (continued)

Scientific Name	Common Name	Photoperiod Response[1]	Irradiance Response[2]	Temperature Group[3]
Centaurea spp.	bachelor's buttons	O/FLDP	—	1
C. cyanus 'Blue Boy'		OLDP	II	1
Centranthus macrosiphon	spurred valerian	DNP	FI	1-2
Cleome hassleriana	spider flower	DNP/OLDP	—	3
C. hassleriana 'Pink Queen'		FLDP	II	3
C. hassleriana 'Rose Queen'		DNP	FI	3
C. spinosa	spiny spider flower	FSDP	—	3
Clerodendrum thomsoniae	bleeding heart vine	DNP	—	—
C. × *speciosum*	red bleeding heart vine	DNP	—	—
Cobaea scandens	cup and saucer vine	DNP	II	1
Convulvulus tricolor 'Blue Enchantment'	morning glory	DNP	FI	2
Cosmos astrosanguineus	chocolate cosmos	FLDP	—	2
C. bipinnatus 'Daiblo'	Mexican aster	FSDP	II	2
C. bipinnatus 'Early Wonder''		FSDP	—	2
C. bipinnatus 'Sensation White'		FSDP	FI	2
C. sulphureus	yellow cosmos	OSDP	—	2
Collinsia heterophylla	Chinese houses	FLDP	II	—
Crossandra infundibuliformis	firecracker flower	DNP	—	—
Cucumis sativus	cucumber	DNP	—	1-2
Dahlia × *hybrida*	dahlia	FSDP	—	1-2
Dendranthema × *grandiflorum*	chrysanthemum	FSDP	—	2
Dianthus barbatus	sweet William	DNP	—	1-2
D. chinensis 'Ideal Cherry Purple'	pinks	FLDP	II	1
Diascia hybrids	diascia	DNP	—	—
Dimorphoteca aurantica 'Mixed Colors'	Cape marigold	DNP	II	2
D. aurantica 'Salmon Queen'		OLDP	—	2
Dolichos lablab	hyacinth bean	OSDP	II	2
Eschscholzia californica	California poppy	FLDP	II	1
Evolvulus glomeratus	evolvulus	LDP	—	—
Exacum affine	Persian violet	DNP	—	—
Fuschia × *hybrida*	hybrid fuschia	OLDP	—	—
F. 'Gartenmeister'		DNP	—	—
Gallardia × *grandiflora*	blanketflower	FLDP	—	2
G. × *grandiflora* 'Goblin'		OLDP	—	2
Gazania rigens 'Daybreak Red Stripe'	treasure flower	OLDP	FI	2
Gerbera jamesonii	gerbera daisy	FSDP	—	2-3
Gomphrena globosa 'Bicolor Rose'	globe amaranth	FSDP	II	3
Gypsophilia elegans	baby's breath	F/OLDP	—	1
G. paniculata		F/OLDP	—	1
G. paniculata 'Snowflake'		OLDP	—	1
Helianthus annuus	sunflower	DNP/FSDP	—	1

Table 1. (continued)

Scientific Name	Common Name	Photoperiod Response[1]	Irradiance Response[2]	Temperature Group[3]
H. annuus 'Big Smile'	sunflower (continued)	FSDP	—	1
H. annuus 'Elf'		FSDP	—	1
H. annuus 'Pacino'		FSDP	—	1
H. annuus 'Sunbright'		FSDP	—	1
H. annuus 'Sundance Kid'		DNP	—	1
H. annuus 'Sunrich Orange'		FSDP	—	1
H. annuus 'Sunspot'		FSDP	—	1
H. annuus 'Teddy Bear'		FSDP	—	1
H. debilis 'Vanilla Ice'		FLDP	II	1
Hibiscus cisplatinus		DNP	—	2-3
H. laevis	halberd-leaf rosemallow	OLDP	—	2-3
H. moscheutos	swamp mallow	OLDP	FI	2-3
H. radiatus	monarch rosemallow	OSDP	—	2-3
H. rosa-sinensis	Chinese hibiscus	DNP	—	2-3
H. trionum	flower-of-an-hour	FLDP	—	2-3
Impatiens balsamina	garden balsam	OSDP	—	2
I. hawkeri	New Guinea impatiens	DNP	—	2-3
I. wallerana	busy lizzy	DNP	—	2
Ipomoea × *multifida* 'Scarlet'	cardinal climber	FSDP	II	2-3
I. spp.		FSDP	—	—
Ipomopsis rubra 'Hummingbird Mix'	standing cypress	OLDP	II	—
Jamesbrittania hybrids	bacopa	DNP	—	—
Lanatana camara	shrub verbena	DNP	—	—
L. montevidensis		DNP	—	—
Lathyrus odoratus 'Royal White'	sweet pea	OLDP	FI	1
Lavatera trimestris 'Silver Cup'	annual mallow	OLDP	FI	1-2
Legousia speculum-veneris	Venus' looking glass	OLDP	II	—
Leonotis menthaefolia	mint scented lion's tail	DNP	—	—
Leptosiphon hybrida		OLDP	II	—
Lilium spp.	lily	FLDP	—	—
Limnanthes douglasii	poached egg plant	OLDP	FI	—
Limonium sinuata 'Fortress Deep Rose'	statice	FLDP	II	2
L. sinuata 'Heavenly Blue'		FLDP	II	2
Linaria maroccana	toadflax	FLDP	FI	—
Linum perenne	blue flax	OLDP	FI	1-2
Lobelia erinus	trailing lobelia	OLDP	—	2
L. erinus 'Crystal Palace'		OLDP	II	2
L. × *speciosa*		FLDP	—	2
L. × *speciosa* 'Compliment Scarlet'		FLDP	—	2

Table 1. (continued)

Scientific Name	Common Name	Photoperiod Response[1]	Irradiance Response[2]	Temperature Group[3]
Lobularia maritima	sweet alyssum	DNP	—	1-2
Lycopersicon esculentum	tomato	DNP	—	2
Matthiola hybrids	stock	FLDP	—	1
M. longipetala 'Straight Sensation'	evening stock	DNP	II	1
Mimulus × hybridus 'Magic'	monkeyflower	OLDP	II	1
Mina lobata	Spanish flag	OSDP	II	—
Mirabilis jalapa	four o'clock flower	OLDP	II	2
Nemophila maculata 'Pennie Black'	five-spot	DNP	FI	3
N. menziesii	baby blue eyes	DNP	II	3
Nicotiana alata	flowering tobacco	DN/FLDP	—	2
N. alata 'Domino White'		DNP	FI	1
Nigella damascena 'Miss Jekyll'	love-in-a-mist	OLDP	II	1
Ocimum basilicum	basil	FSDP	—	2
Oenethera pallida 'Wedding Bells'	pale evening primrose	OLDP	II	1
Origanum vulgare	oregano	DNP	FI	1
Osteospermum hybrids	African daisy	FLDP	—	—
Oxypetalum caerulea 'Blue Star'	tweedia	DNP	FI	2
Pelargonium × domesticum	regal geranium	FLDP	—	—
P. × hortorum	zonal geranium	DNP	FI	—
P. peltatum	ivy geranium	DNP	—	—
Pentas lanceolata	Egyptian starflower	FLDP/DNP	—	—
Perilla frutescens	green shiso	?SDP	—	2
Petunia × hybrida	petunia	FSD/OLDP	—	2
P. × hybrida 'Cascadia Charme'		FSDP	—	2
P. × hybrida 'Cascadia Improved Charlie'		FLDP	—	2
P. × hybrida 'Doubloon Blue Star'		FLDP	—	2
P. × hybrida 'Fantasy Pink Morn'		OLDP	—	2
P. × hybrida 'Marco Polo'		FLDP	—	2
P. × hybrida 'Petitunia Bright Dream'		FLDP	—	2
P. × hybrida 'Purple Wave'		OLDP	FI	2
P. × hybrida 'White Storm'		FLDP	—	2
Phacelia campanularia	desert bells	DNP	II	—
P. tanacetifolia	lacy phacelia	FLDP	II	—
Pharbitis nil	morning glory	FSDP	—	1-2
Phlox chinensis	annual phlox	FLDP	—	1
Polemonium viscosum	sky pilot	OLDP	II	—
Portulaca grandiflora	moss rose	DNP	—	2
P. oleracea	flowering purslane	DNP	—	—
Primula malacoides	fairy primrose	OSDP	—	1
P. obconica	German primrose	DNP	—	1
P. × polyantha	English primrose	DNP	FI	1

Table 1. (continued)

Scientific Name	Common Name	Photoperiod Response[1]	Irradiance Response[2]	Temperature Group[3]
Rosa × *hybrida*	rose	DNP	FI	—
Rudbeckia spp.	black-eyed Susan	OLDP	—	1
Salpiglossus sinuata	painted tongue	FLDP	—	1
Salvia farinacea	mealy sage	FLDP	FI	2-3
S. splendens 'Vista Red'	scarlet sage	FLDP	II	2
Sanvitalia procumbens	Mexican creeping zinnia	FSDP	II	2
Scabiosa columbaria	pincushion flower	?DNP	—	1-2
Scaevola aemula	fan flower	DNP	—	—
Silene armeria 'Elektra'	catchfly	OLDP	FI	—
Sinningia speciosa	gloxinia	DNP	—	—
Solenostemon spp.	coleus	?SDP	—	3
Solidago spp.	goldenrod	SDP	—	—
Sutera cordata	bacopa	DNP	—	—
Streptocarpus × *hybridus*	Cape primrose	DNP	FI	—
Tagetes erecta	African marigold	FSDP	—	2
T. patula	French marigold	DNP	—	2
T. tenuifolia	signet marigold	FSDP	—	2
Thunbergia alata	black-eyed Susan vine	DNP	II	2
Tithonia rotundifolia	Mexican sunflower	FLD/FSDP	—	2
T. rotundifolia 'Fiesta Del Sol'		FLDP	II	2
T. rotundifolia 'Sundance'		FSDP	FI	2
Torenia fournieri	wishbone flower	?DNP	—	2-3
Verbascum phoeniceum	mullein	DNP	II	1
Verbena × *hybrida*	verbena	?LDP	—	2
Viguiera multiflora	goldeneye	FLDP	II	—
Viola tricolor	violet	F/OLDP	II	1
V. × *wittrockiana*	pansy	FLDP	FI	1
Zinnia angustifolia	creeping zinnia	DNP	—	2-3
Z. elegans 'Benary Giant Deep Red'	zinnia	FLDP	—	2
Z. elegans 'Exquisite Pink'		FSDP	II	2
Z. elegans 'Oklahoma'		FSDP	—	2
Z. elegans 'Peter Pan Scarlet'		FSDP	II	2

Source: Table material adapted from A.M. Armitage (1994, Growing-on), M. Karlsson and R. Larson. (1994, Light, Temperature, and Carbon Dioxide), J.E Erwin and R.M. Warner (1999, Temperature), W.H. Carlson, M.P. Kaczperski, and E.M. Rowley (1993, Bedding Plants), J. Erwin, N. Mattson, and R. Warner (2004, Light Effects on Annual Bedding Plants).

[1]SD=short-day photoperiodic response. LD=long-day photoperiodic response. F=facultative response. O=obligate responses. ? =F or O response unknown.

[2]FI=facultative irradiance response. II=irradiance indifferent response. — = response unknown.

[3]Ideal temperature ranges. 1=55-65°F. 2=63-68°F. 3=65-75°F. — = data not available. Other factors (such as light levels, time of year, location, and energy consumption) should be taken into consideration.

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6/11