New Directions For Scheduling Bedding Plants

Chinese aster forced to flower simultaneously using photoperiodic treatments. (Photos: John Erwin)

Seedlings' Juvenile Period Lengths Identified By Node Number

Species	Node Number When Plants Become Competent To Flower
Aquilegia 'McKana's Giant'	12 nodes
Aquilegia 'Fairyland'	15 nodes
Calceolaria herbeohybrida	5 nodes
Callistephus chinensis	4 nodes
Coreopsis grandiflora 'Sunray'	8 nodes
Gaillardia x grandiflora 'Goblin'	16 nodes
Heuchera sanguinea 'Bressingham'	19 nodes
Lavandula angustifolia 'Munstead'	18 nodes
Rudbeckia fulgida 'Goldstrum'	10 nodes

Figure 1. This figure shows the node numbers when different annuals and perennials transition from immature to mature plants. (Adapted from Yuan, 1995; Whitman, 1995; Sheldron and Weiler, 1982)

Many factors affect flowering times. Researchers at the University of Minnesota and Michigan State University are developing ways growers can use those factors to flower their crops at specific times.

By John Erwin and Erik Runkle

The importance of scheduling flowering is increasing as retail outlets require marketing plants with color and the need to minimize space, labor, and heating and electrical costs swells. The floriculture production programs at the University of Minnesota, St. Paul, Minn., and Michigan State University, East Lansing, Mich., have focused on identifying what factors affect flowering of ornamental crops and developing ways that growers can use that information to flower crops at desired times. Some of that work will be summarized in this article.

In addition, we are introducing three new concepts that we will elaborate on in future articles. These concepts and additional research information may greatly increase the ability of growers to schedule bedding plants effectively.

Maturity Stages

Seed-propagated plants transition from an "immature" to a "mature" state as they age. This same phenomenon occurs with animals, birds and many other life forms; most animals and birds are incapable of reproducing immediately after birth. They must first grow and develop to a specific age before they can produce offspring. Similarly, plants must reach a developmental stage before they can produce flowers. Therefore, growers cannot induce flowering until a crop has transitioned from an immature to a mature state.

Plant species differ in when they transition from immaturity (the juvenile stage) to maturity (the mature stage). For instance, many annual bedding plants transition from the juvenile to mature stage very early in development, usually during the first month after germination. Herbaceous perennials often take 3-6 months to transition to a mature state, whereas trees can require more than 10 years. In nearly all instances, plants that are propagated by stem cuttings are mature; thus, maturity is not an issue with these crops.

How can we tell when a plant is mature? The temperature at which we grow a crop controls how fast the crop develops. A crop grown for three weeks at 70° F will obviously be larger and have more leaves than a crop grown for three weeks at 60° F. Therefore, we have to measure a plant's developmental age in a different way than time.

We believe the best way to measure plant maturity is to count the number of nodes that have unfolded on the main stem. (A node is the point of leaf attachment to the stem. Plants with an opposite leaf arrangement have two leaves per node, whereas plants with an alternative leaf arrangement on the stem have one leaf per node.)

For instance, petunia 'White Storm' and 'Purple Wave' transition from immature to mature plants when they have unfolded one and four nodes, respectively. In contrast, a perennial crop such as heuchera (coral bells) may need to unfold 14 nodes before seedlings become mature plants.

Figure 1, left, shows the node numbers when different annuals and perennials transition from immature to mature plants. Remember, cuttings taken from stock plants are almost always mature and are capable of flowering and, thus, vegetative annuals and perennials are not included in the table.

Flower Induction

Once a plant is mature, it can be induced to flower. The conditions that promote flowering vary with species. For instance, some species are induced to flower by the day length (or photoperiod) plants are grown under. Some species are induced to flower by the total amount of light plants receive per day. Some species, particularly perennials, are induced to flower by a period of cold temperature (optimally 42-48° F), which is known as a vernalization treatment. The sections below review how photoperiod and total light per day affect flowering in bedding plants.

Photoperiod. Once plants are mature and have gained the competence to flower, flowering in some species can be controlled by day length or photoperiod. Most plants can be categorized into five photoperiodic response groups based on how photoperiod influences their flowering:

- Facultative short-day plant (flowering occurs earlier under short days)
- Obligate short-day plant (flowering occurs only under short days)
- Facultative long-day plants (flowering occurs earlier under long days)
- Obligate long-day plants (flowering occurs only under long days)
- Day-neutral plants (flowering is not influenced by photoperiod)

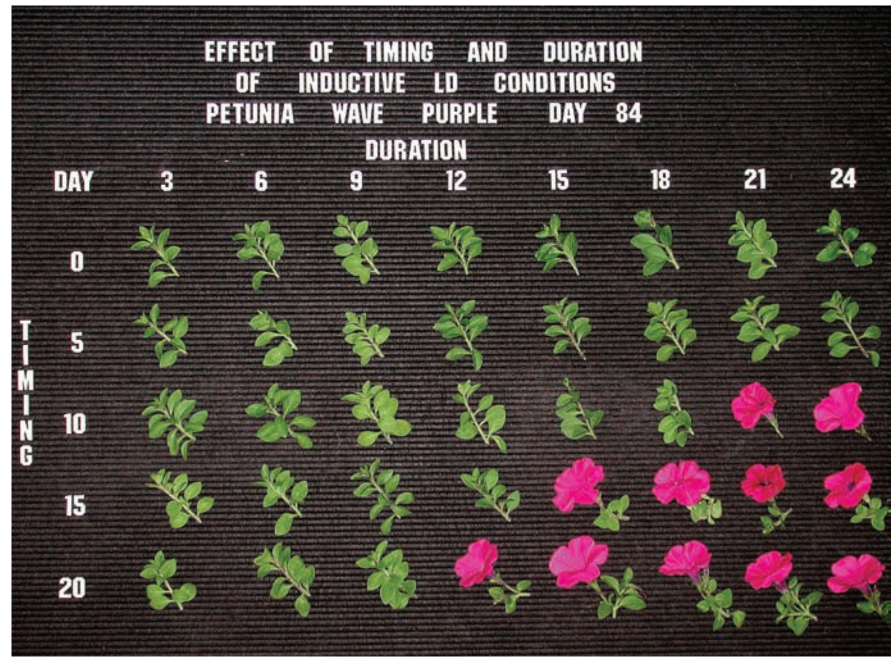
Many bedding plants are photoperiodic, meaning time to flower is influenced by the photoperiod that plants are grown under. Figure 2, right, shows the photoperiodic response groups for 25 common bedding plants. Placing mature seedlings or cuttings under the photoperiod that induces flowering will result in the quickest flowering.

Total light per day. Some bedding plants flower quicker when grown under high light levels. Why is this? Our controlled studies have identified that some plants transition from the immature to mature stage earlier when seedlings are grown under a high daily light integral (DLI) (high total amount of light per day). When a plant flowers earlier under high light intensities (more total light per day), the plant has a facultative irradiance response. When flowering time is not accelerated by high light intensities, the plant has an irradiance indifferent response. Figure 2, right, shows the irradiance response groups of 25 bedding plants.

How do we measure the light a plant can use? A foot-candle meter is not the best way to measure lighting for plant growth because a foot-candle is based on the light a human eye can see and not what a plant can use. Plants respond to photosynthetic light, and, thus, the appropriate meter that should be used by growers when measuring lighting for plant growth is a quantum sensor or quantum meter.

A quantum sensor measures only the light a plant uses for photosynthesis. Even more helpful than a quantum sensor is a light integrator, which measures the number of moles of photosynthetic light per day as well as the intensity of that light at any point in time. Using irradiance response groups to help schedule flowering will require you to have a light integrator, since the irradiance response categories are based on the average DLI.

Facultative irradiance plants flower earlier as the moles of light ➧

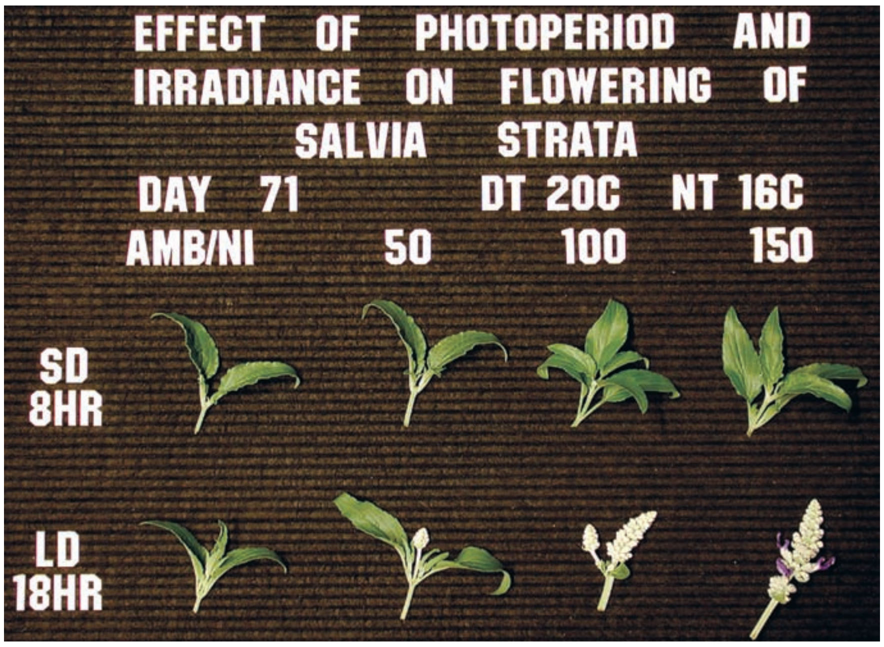


Petunia 'Purple Wave' shoot tips taken from plants 84 days old. Plants were exposed to long days (18-hour day) for different lengths of time (duration in days) and different stages in development after germination (timing, days).

Photoperiodic Response Groups For 25 Common Bedding Plants

Species	Cultivar	Photoperiod	Irradiance
Ageratum	'Blue Danube'	FLDP	II
African marigold	n/a	FSDP	Z
Black-eyed Susan vine	n/a	DNP	II
Blue salvia	'Strata'	FLDP	FI
Celosia	'Flamingo Feather Purple'	OSDP	II
China aster	n/a	FLDP	Z
Cleome	'Rose Queen'	DNP	FI
Cosmos	'Sensation White'	FSDP	FI
Dianthus	'Ideal Cherry Picotee'	FLDP	II
Fibrous begonia	n/a	DNP	FI
French marigold	n/a	DNP	II
Gazania	'Daybreak Red Stripe'	OLDP	FI
Geranium (seed)	n/a	DNP	FI
Gomphrena	'Bicolor Rose'	FSDP	II
Impatiens	n/a	DNP	II
Lavatera	'Silver Cup'	OLDP	FI
Lobelia	'Crystal Palace'	OLDP	II
Mimulus	'Magic'	OLDP	II
Nicotiana	'Domino White'	DNP	FI
Pansy	n/a	FLDP	FI
Petunia	'Purple Wave'	OLDP	FI
Salvia	'Vista Red'	FLDP	II
Snapdragon	n/a	FLDP	FI
Stock	'Starlight Scentsation'	DNP	II
Zinnia	'Exquisite Pink'	FSDP	II

Figure 2. Photoperiodic and irradiance classifications based on mean node number below the first open flower. Photoperiod classifications: FSDP = facultative short-day plant; FLDP = facultative long-day plant; OSDP = obligate short-day plant; OLDP = obligate long-day plant; DNP = day-neutral plant. Irradiance classifications: FI = facultative irradiance response (supplemental irradiance hastens flowering); II = irradiance indifferent response (increasing irradiance does not hasten flowering). Z = We do not know the irradiance response group yet.



Blue salvia 'Strata' shoot tips taken from plants grown with a 68° F day temperature and a 61° F night temperature under short days (8 hours) or long days (night interruption (NI) or with extended days (+25, +50, +100)). Plants were grown under natural daylight (St. Paul, Minn.) with no supplemental lighting or supplemental 50, 100 or 150 umol m-2 s-1 (+250, 500 or 750 foot-candles).

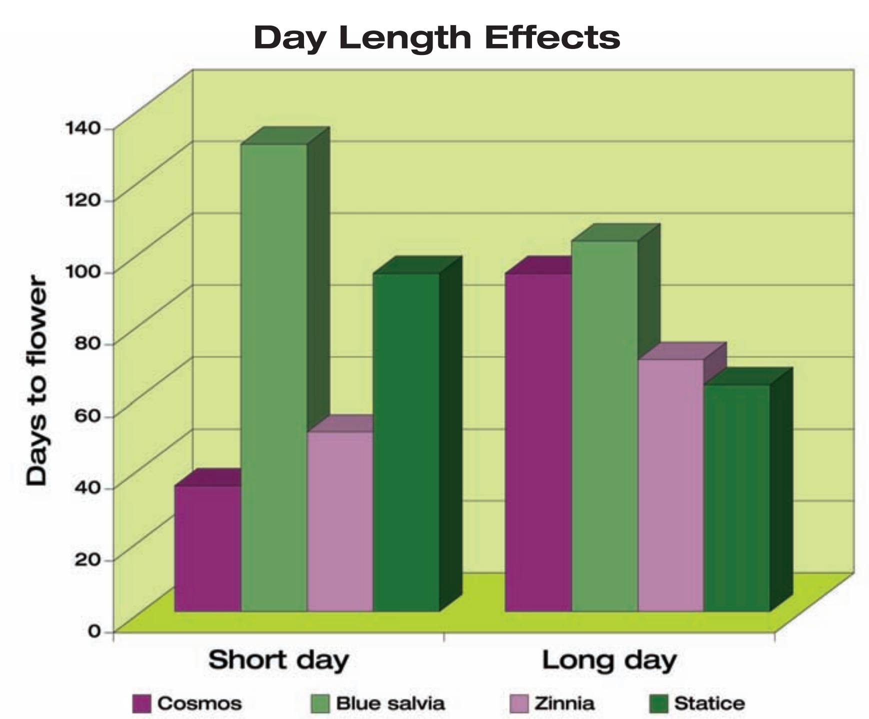


Figure 3. This shows the effect of growing different bedding plant species under either short days (natural daylight, 8 hours) or long days (natural daylight + night interruption (NI) lighting (NI; 10 foot-candles from 10 p.m. to 2 a.m.)) on days to flower (germination until first open flower).

Bedding Plant Response Groups

Plant Type	Cultivar	Response Group
Impatien	'Super Elfin Lipstick'	8 weeks
Petunia	'Avalanche Pink'	7 weeks
	'Dreams Rose'	7 weeks
	'Purple Wave'	8 weeks
Pansy	'Colossus Yellow Blotch'	9 weeks
	'Delta Pure White'	9 weeks
	'Crystal Bowl Supreme Yellow'	7 weeks
Viola	'Sorbet Blackberry Cream'	7 week

Figure 4. These are response groups of different bedding plants. Developed from data collected in experiments conducted at the University of Minnesota (Erwin, personal observation).

per day increase. When does increasing light no longer result in earlier flowering? Our research, which is reinforced by growers' experiences, suggests that growers will see a benefit with most bedding plants as total light per day increases from 2 to 12-14 moles. A few crops, such as nicotiana, benefit from an even higher DLI, but most benefit from up to 12-14 moles of light per day.

Scheduling

Scheduling flowering in bedding plants has been difficult in the past. Flowering times can vary from year to year and from greenhouse to greenhouse. We are introducing three new terms that, if used by the industry, will help growers schedule crops. In addition, we advocate that supply companies and researchers use these terms when developing crop schedules so there is consistency across the industry. The three new concepts we are proposing for bedding plant scheduling are: response groups, grow times and re-bloom time. Each of these is defined below.

Response groups. We are introducing the concept of "response groups" for bedding plant production. The industry is familiar with the concept of response groups for potted plants, such as poinsettia or chrysanthemum. The response group of a potted poinsettia or chrysanthemum is the time from the beginning of inductive conditions (short days with poinsettias and mums) until the time of open flowering when grown at 68/65° F day/night temperatures. The response group varies among species and cultivars.

We define response group of a bedding plant as the time from the start of inductive conditions on mature plants until flowering when grown at 68° F day and night. This is slightly different than response groups developed for potted plants in that both the day and night temperatures are 68° F. The rationale for this is there are a number of bedding plants (New Guinea impatiens, melampodium, cleome, vinca, etc.) that can develop very slowly at temperatures less than 68° F. In addition, using a 68/65° F day/night temperature standard may not be the best standard temperature regime because day length varies during a year and in different parts of the country and, therefore, the flowering time will vary because the average daily temperature varies. Using a constant 68° F temperature standard eliminates this problem.

By using the response group concept, growers can identify exactly how long it will take from the start of an inductive treatment (such as long days for obligate long-day plants) until first flowering. This would greatly simplify scheduling! In time, we hope to develop tables where growers can have the response groups at different temperatures, but for now, we suggest an industry standard of reporting response times at the standard constant 68° F temperature.

Grow time. Some growers may not want to monitor when plants are transitioning from immature to mature plants or the information may simply not exist. How can we more easily schedule flowering in these crops? We need to resurrect the term "grow times," but in a new way. Production times or grow times of some bedding plant crops have been reported in the past but are hard to compare because many are determined using different (and sometimes unmonitored) temperatures and photoperiods.

Therefore, we are resurrecting the term and defining it with standardized conditions. We are defining the grow time of a seed crop as the time it takes from germination until flowering under inductive conditions (juvenile period + response group) when grown at a constant 68° F. Such information would be very helpful for growers to schedule crops as well as enable comparisons of new varieties to existing bedding plant crops.

With time, such information should be provided to growers from university researchers and seed companies at a variety of temperatures. Currently, we are determining grow times for more than 50 bedding plants this winter and spring at the University of Minnesota in association with Wagner's Greenhouses, Minneapolis and Hugo, Minn. Researchers at Michigan State University are determining grow times for approximately 20 seed-propagated annuals at varying temperatures (including constant 68° F). Eventually, there will likely be grow times for a variety of crops at different temperatures.

Re-bloom time. More and more growers are rooting nonrooted cuttings or are buying rooted cuttings. Scheduling these cuttings to have them in flower after pinching on a specific date can be difficult. John Erwin is presently working with Pleasant View Gardens, Loudon, N.H., to determine the time from pinching liners until re-blooming for some vegetative crops grown at temperatures ranging from 54 to 78° F. As a result of this work, we believe the industry needs a standardized term to report this information to help growers schedule flowering times after pinching across suppliers and universities.

We are proposing the term "re-bloom time" as the time it takes from pinching a cutting until the first flower opens on the shoots that arise after the pinch when grown at a constant 68° F. Re-bloom time certainly varies among species. For instance, the re-bloom time for angelonia 'Angelface Blue' grown at a constant 68° F is 56 days. In contrast, the re-bloom time for petunia 'Supertunia Bordeaux' grown at 68° F is 32 days. With this information, growers can effectively re-bloom different species for the same date by pinching those species at different times. We are currently working with a number of growers to develop re-bloom times for different vegetatively propagated crops.

Monitoring

Although we would like to have absolutely constant temperatures to effectively schedule a crop, it is impossible in commercial greenhouses. Therefore, we have been looking at ways to allow growers to realistically and more easily monitor crop development.

We are proposing a new way of monitoring crops that is similar to the concept of graphical tracking used for monitoring plant height. Instead of plant height, we are proposing establishing developmental tracks that will allow growers to determine if a crop is ahead or behind schedule at any point in development. A developmental track is based on two pieces of information: degree hours (or degree days) required to flower a crop under inductive conditions and the time in which you desire to do that.

For example, apple production time is often tied to the number of degree days that a plant accumulates in the spring. Degree days are calculated by accumulating the time that the temperature is above the base temperature of a plant (often 40° F). Apple trees bloom ➧

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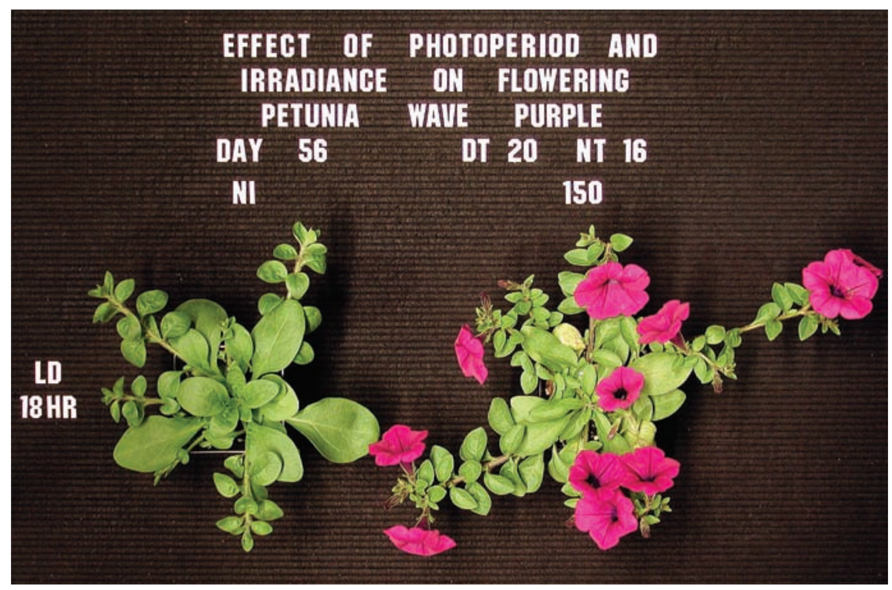

This is the effect of delivering long days to petunia 'Purple Wave' in two different ways (night interruption lighting versus supplemental lighting during the day and extending days from 4 p.m. to 2 a.m. with high-pressure sodium lights) on flowering. Plants were 56 days old from germination and were grown with 68° F days and 61° F nights.

when they accumulate a specific number of degree days. We are using a similar concept to apply to bedding plant production.

If we know how many degree days, or degree hours, a plant needs to reach a flowering size, then a grower can determine on a daily or weekly basis what temperature he or she needs to grow the crop at to have it flower at a desired time. Conversely, a grower can tell how many days ahead or behind he or she is. We will be working with Paul Fisher at the University of Florida, Gainesville, Fla., to develop developmental tracks using computer software programs for different seed-propagated bedding plants and vegetative liners.

This concept will provide growers with a developmental track model where they will be able to determine if a crop is developmentally ahead or behind schedule at any point in development. This will allow growers to make temperature management decisions on a daily or weekly basis to ensure that their crops flower when they need them, they adjust shipping selling dates accordingly and/or they do not spend more money heating a crop than needed.

Conclusions

These new tools and concepts could greatly increase the ability of growers to effectively schedule bedding plants. The concept of response groups would allow growers to effectively schedule bedding plants as we do with chrysanthemum and poinsettias. The concept of grow times would increase the ease in scheduling crops from germination to finish for bedding plant growers. The concept of re-bloom times would allow growers to effectively schedule flowering of vegetative annual liners. Collectively, the application of these concepts could increase the ability to schedule crops and, if accepted as industry standards, allow direct comparisons between growers and provide a standard for information from suppliers and propagators. GPN

John Erwin is professor in the Department of Horticulture Science at the University of Minnesota, St. Paul, Minn. He can be reached at erwin001@umn.edu. Erik Runkle is assistant professor and floriculture extension specialist in the Department of Horticulture at Michigan State University, East Lansing, Mich. He can be reached at runkleer@msu.edu.

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