

Flowering Annuals and Perennials When You Want!

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Bedding and perennial growers need to have a better understanding of flowering than any other agricultural sector. You have to schedule flowering of over 100 species/varieties from all over the world during a 1-2 month period under changing environmental conditions.



2

Blooming annuals and perennials during the peak marketing period (spring) can greatly increase sales of plants that naturally flower later.



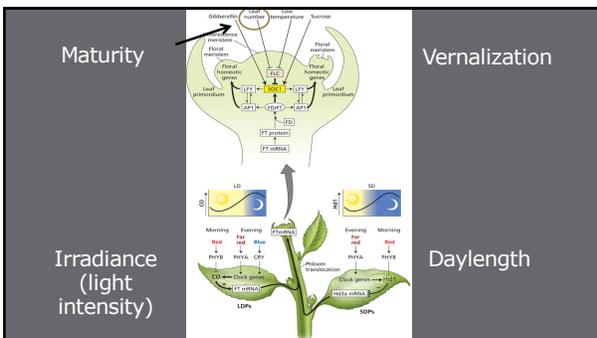
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Scheduling Flowering

- General Concepts: Flowering and Development Rate
- Seed Propagated Flowering Plants
- Asexually Propagated Plants (Cuttings, Division, Tissue Culture)




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Maturity

Vernalization

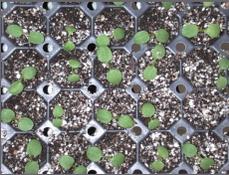
Irradiance (light intensity)

Daylength

5

Juvenility versus Maturity

- Plants are 'immature', or juvenile, after germination. Juvenile plants are incapable of flowering.
- As a plant ages (unfolds leaves), the shoot tip transitions to mature phase. Mature plants can be induced to flower.



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Juvenile Period Lengths - Woody Plants

Crop	Time
Rose	20-30 days
Grape	1 year
Orchid spp.	1-7 years
Apple	4-8 years
Orange	5-8 years
English Ivy	5-10 years
Redwood	5 - 15 years
Sycamore	15-20 years
English Oak	25-30 years
European Beech	30-40 years

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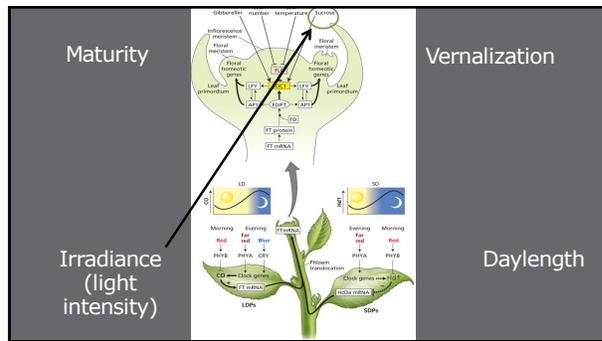
Juvenile Period Lengths - Herbaceous Plants

Crop	Node Number
<i>Aquilegia</i> 'McKana's Giant'	12 nodes
<i>Aquilegia</i> 'Fairylad'	15 nodes
<i>Calceolaria herbeohybrida</i>	5 nodes
<i>Callistephus chinensis</i>	4 nodes
<i>Coreopsis grandiflora</i> 'Sunray'	8 nodes
<i>Gaillardia x grandiflora</i> 'Goblin'	16 nodes
<i>Heuchera sanguinea</i> 'Dressingham'	19 nodes
<i>Lavandula angustifolia</i> 'Munstead'	18 nodes
<i>Rudbeckia fulgida</i> 'Goldstrum'	10 nodes
<i>Petunia hybrida</i> 'Purple Wave'	4 nodes
<i>Viola x wittrockiana</i> 'Delta Pure White'	3-4 nodes

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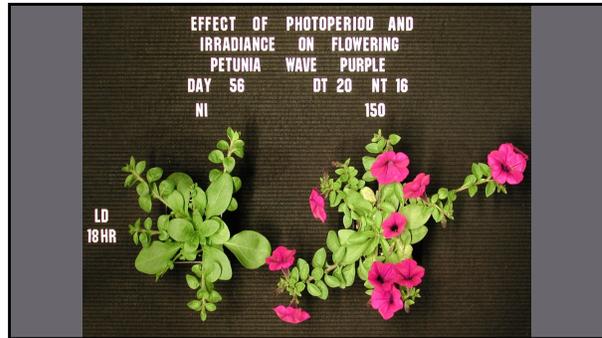
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The juvenile period length can be shortened by increasing light intensity (irradiance) with many, but not all, bedding plants.

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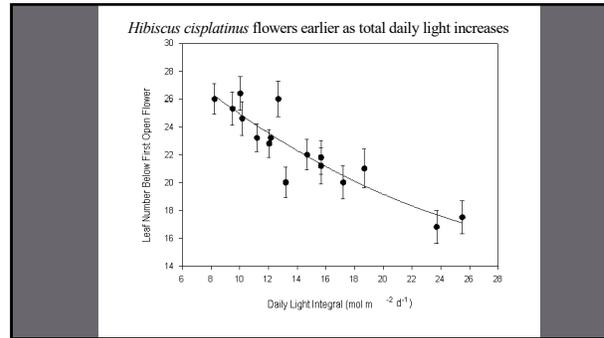
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Irradiance Response Groups

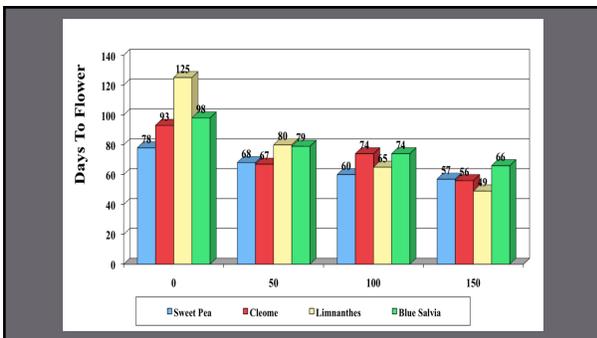
- Facultative Irradiance Plants:** Leaf number below the first flower decreases as light intensity increases.
- Irradiance Indifferent Plants:** No impact of increasing light intensity on leaf number below the first flower.



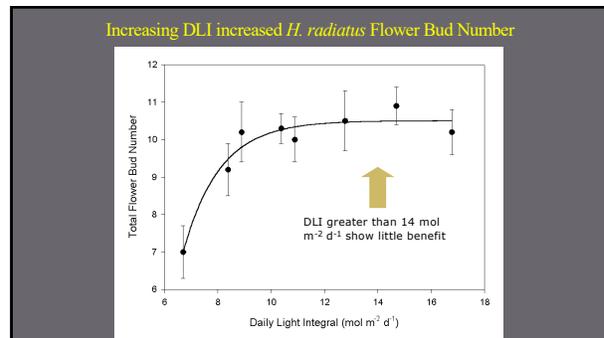
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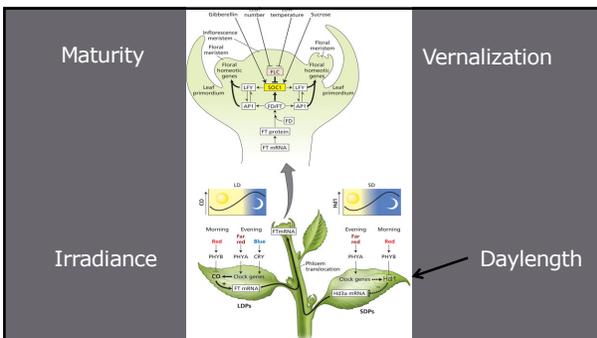
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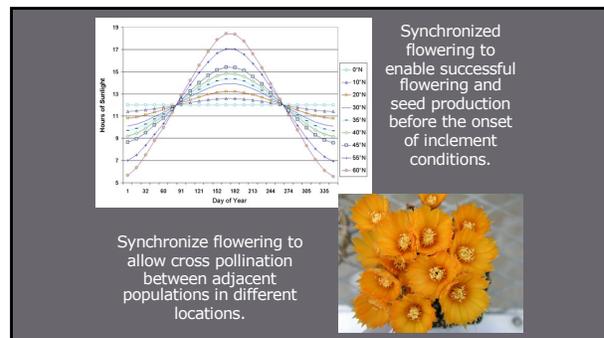
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18

Evidence strongly suggests that the protein FT is behaving as a plant growth regulator and is the long sought 'florigen'.

flowering locus T (FT)

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EFFECT OF PHOTOPERIOD AND IRRADIANCE ON FLOWERING

	MINA	LOBATA	NT 16
DAY	39	DT 20	NT 16
AMB/NI	50	100	150

Obligate Short Day Plant

Plants only flower when grown under short days.

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EFFECT OF PHOTOPERIOD AND IRRADIANCE ON COSMOS DEVELOPMENT

	NATURAL	25	50
		1.6 M	3.2 M
D 82			

Facultative Short Day Plant

Plants flower earlier and with fewer nodes below the first flower when grown SD than LD.

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EFFECT OF PHOTOPERIOD AND IRRADIANCE ON CELOSIA DEVELOPMENT

	NATURAL	25	50
		1.6 M	3.2 M
D 82			

22

EFFECT OF PHOTOPERIOD AND IRRADIANCE ON FLOWERING OF ZINNIA ELEGANS

	DAY 40	DT 20C	NT 16C	
	AMB/NI	50	100	150
8HR SD				
18HR LD				

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TEMPERATURE AND LIGHTING EFFECTS ON DEVELOPMENT OF COMPHRENA GLOBOSA 'GNOME PINK'

12 WKS GERM 11 WKS TRTMT

DAY TEMP 25°C

NIGHT TEMP °C

	15	20	25	30
NI				
SD				

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EFFECT OF PHOTOPERIOD AND IRRADIANCE ON LOBELIA DEVELOPMENT

DAY 70 0 25 50

SD 8 HR
LD NI

Obligate Long Day Plant

Plants only flower when grown under long days.

25

EFFECT OF PHOTOPERIOD AND IRRADIANCE ON FLOWERING PETUNIA WAVE PURPLE

DAY 98 DT 20 NT 16

AMB/NI 50 100 150

8 HR SD
18 HR LD

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EFFECT OF PHOTOPERIOD AND IRRADIANCE ON LAVATERA DEVELOPMENT

D 82 NATURAL 25 50

1.6 M 3.2 M

SHORT DAY 8 HR
LONG DAY 18 HR

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EFFECT OF PHOTOPERIOD AND IRRADIANCE ON FLOWERING PANSY DELTA PURE WHITE

DAY 56 DT 20 NT 16

AMB/NI 50 100 150

SD 8HR
LD 18HR

Facultative Long Day Plant

Plants bloom earlier with fewer nodes below the first flower when grown under LD compared to SD.

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EFFECT OF PHOTOPERIOD AND IRRADIANCE ON DIANTHUS DEVELOPMENT

D 60 NATURAL 25 50

1.6 M 3.2 M

SHORT DAY 8 HR
LONG DAY 18 HR

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EFFECT OF PHOTOPERIOD AND IRRADIANCE ON FLOWERING IMPATIENS SUPER ELFIN LIPSTICK

DAY 58 DT 20 NT 16

AMB/NI 50 100 150

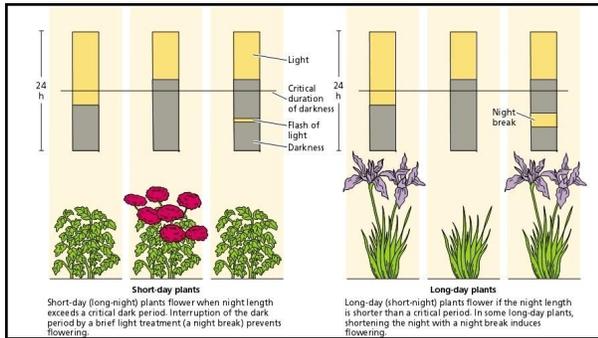
SD 8HR
LD 18HR

Mathiola longipetala

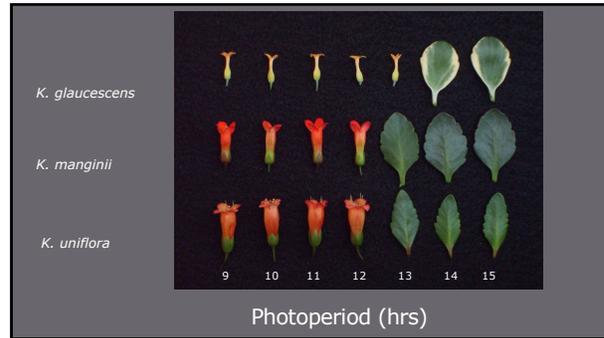
Day Neutral Plants

Plants flower at the same time developmentally under SD or LD.

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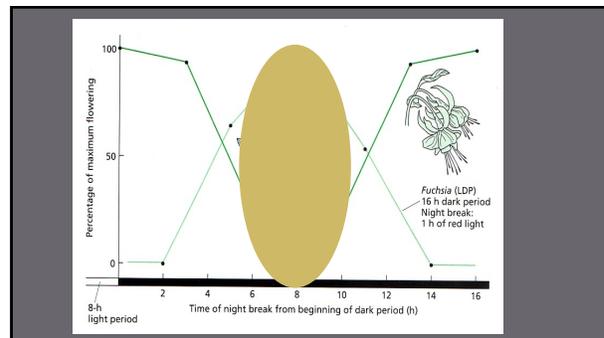


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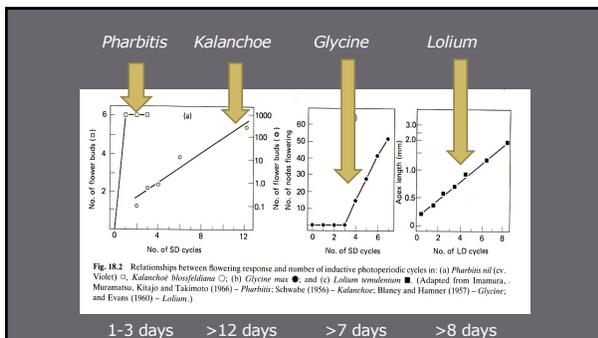
Ways To Manipulate Photoperiod

- Providing Long-days (short nights)
 - Night interruption (10 pm - 2 am; 2 $\mu\text{mol m}^{-2} \text{s}^{-1}$ - 10 footcandles)
 - Incandescent, 'Flowering LEDs' (must have Far red light for LDP!), High pressure sodium lights.
 - When night temperatures drop below 63 °F, NI lighting duration and/or intensity needs to be increased.
- Providing Short-days (long nights)
 - Pull black cloth, generally from 6-8 pm until 8 am.
 - If night temperatures at 12 am are above 74°F, you need to increase night length - usually to 15 hrs.

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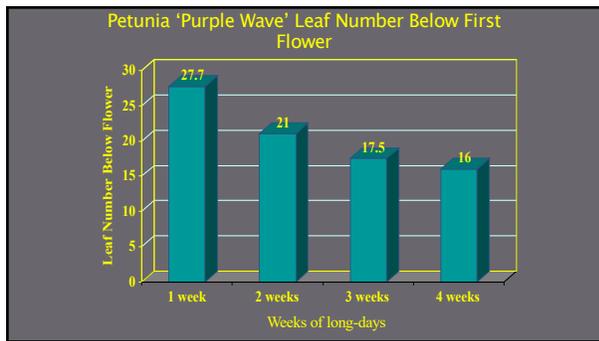
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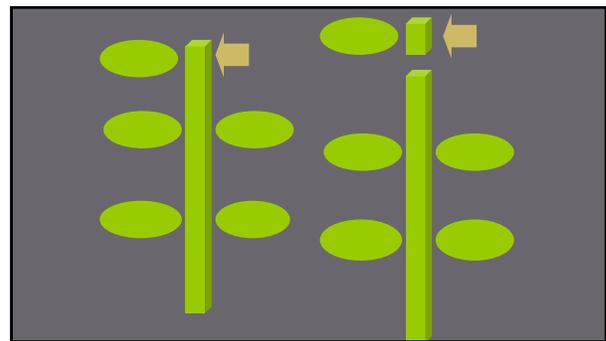
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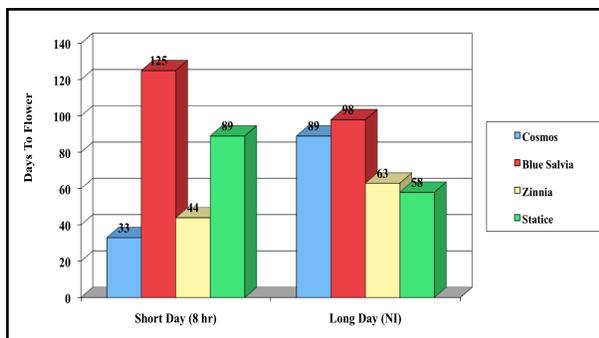
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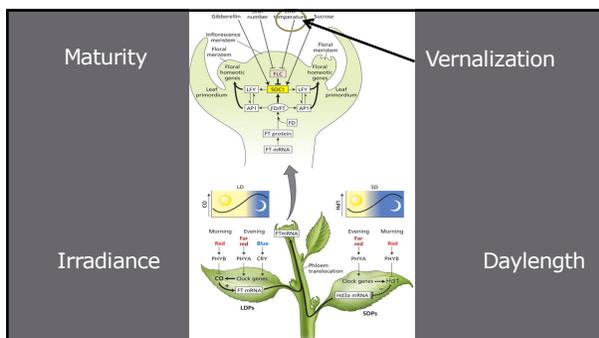
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Bedding Plant Response Groups		
Plant Type	Cultivar	Response Group
Impatiens	'Super Elfin Lipstick'	8 weeks
Petunia	'Avalanche Pink'	7 weeks
	'Dreams Rose'	7 weeks
	'Purple Wave'	8 weeks
Pansy	'Colossus Yellow Blotch'	9 weeks
	'Delta Pure White'	9 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).

'Response Group' is the length of time from the beginning of flower induction until flowering with an average daily temperature of 65-68 °F.

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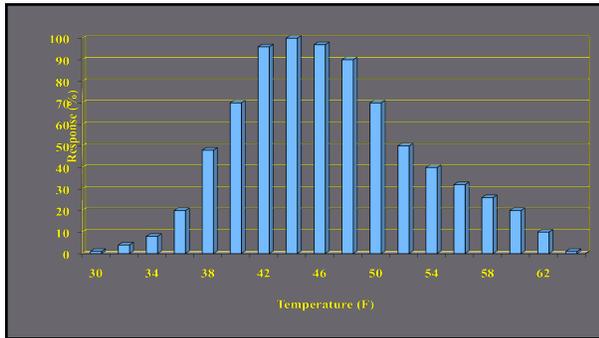


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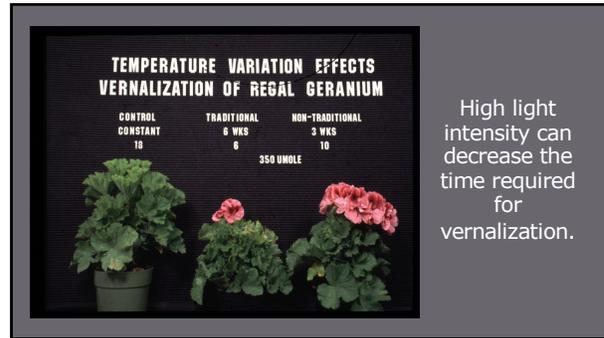
Vernalization

Once mature some plants, like many perennials and Marth Washington geraniums and many Osteospermum – require an extended cold period to induce flowering. Cool temperature induction of flowering is called 'vernalization'. Vernalization occurs in the shoot tip.

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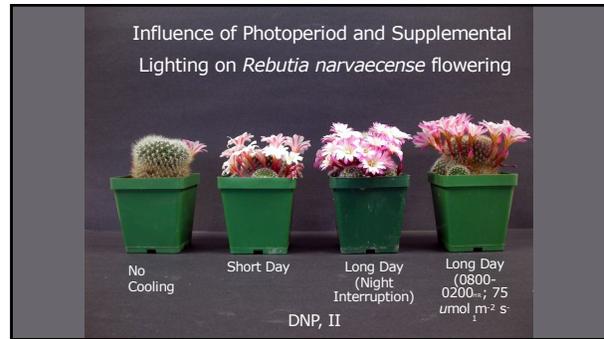
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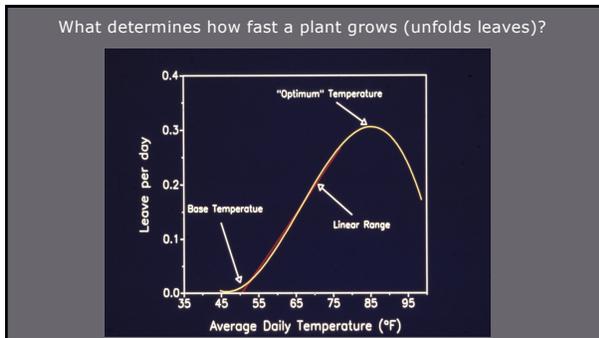
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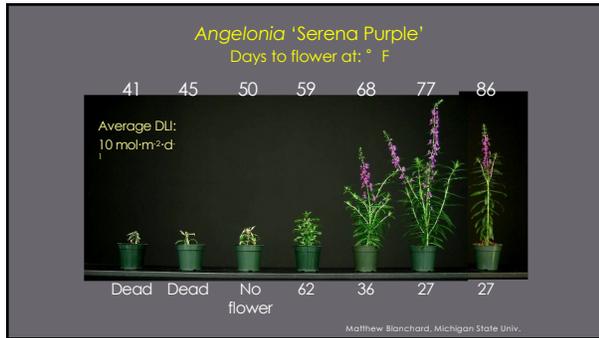
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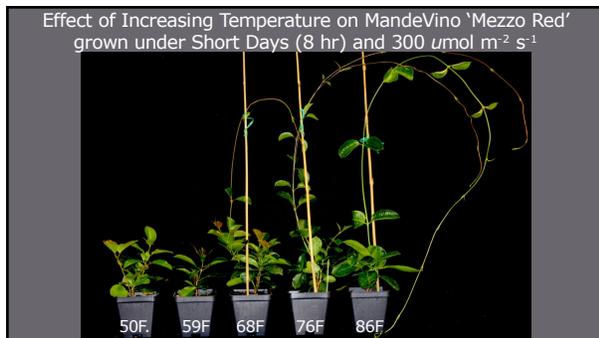
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Plant	Delay when average daily temperature is reduced 10F
Angelonia 'Angelface White'	2.4 days
Blue Salvia 'Strata'	3.1 days
Calibracoa 'Superbells Pink'	1.5 days
Diascia 'Flying Colors Coral'	1.2 days
Gazania 'Daybreak Red Stripe'	1.5 days
Nemesia 'Sunsatia Peach'	0.8 days
Pansy 'Delta Pure White'	1.0 days/1.6 days
Petunia 'Avalanche Pink'	2.5 days
Petunia 'Purple Wave'	3.3 days
Impatiens 'Super Elfin Lipstick'	1.8 days
Snapdragon 'Liberty Bronze'	1.6 days
Viola 'Sorbet Blackberry Cream'	1.1 days

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- Plants for a high temperature house (68–78°F) – based on DTF
- Angelonia
 - Blue Salvia
 - Purple Wave Petunia
 - Mercardonia
 - Scaevola
 - Browallia
 - Cleome
 - Canna
 - Tomato
 - Coleus
 - Pentas
 - Zinnia
 - Vinca
 - Melampodium
 - Gomphrena
 - Cosmos
 - Celosia
 - Pepper
 - Basil
 - Many grasses

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- Plants for a moderate temperature house (63–72°F) – based on DTF
- Calibracoa
 - Gazania
 - Impatiens
 - Snapdragon
 - Petunia 'Supertunia Bordeaux'
 - Verbena 'Superbena Burgundy'
 - Cosmos
 - African Marigold
 - Ageratum
 - Some petunias
 - Portulaca
 - Red Salvia
 - Cosmos
 - Sunflowers

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- Plants for a low temperature house (55–65°F) – based on DTF
- Argyanthemum
 - Osteospermum
 - Pansy
 - Viola
 - Diascia
 - Nemesia
 - Dahlia
 - Some lobelia
 - French marigold
 - Some petunias
 - Some snapdragons
 - Dianthus
 - Alyssum

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Scheduling Flowering

- General Concepts: Flowering and Development Rate
- **Seed Propagated Flowering Plants**
- Asexually Propagated Plants (Cuttings, Division, Tissue Culture)




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In general,

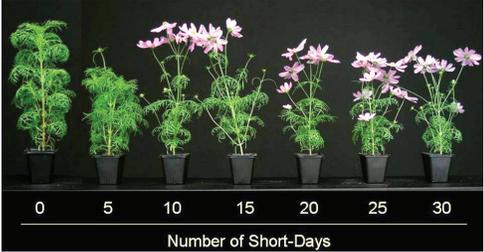
- Most plants should be induced to flower as soon as it germinates.
- Plants with a short juvenile period (less than 2–3 leaves) should be initially (first 2–3 weeks) be grown under conditions that **do not induce flowering** especially if finished in a >4" or larger container.
- Plants require 3 weeks to completely induce flowering.
- During March–May, plants will generally flower 5–6 weeks after beginning flower induction.

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Early in spring, it is very common for a number of short-day/facultative short-day plants such as Cosmos, Celosia and Zinnia to bloom too early resulting in an unsaleable plant.



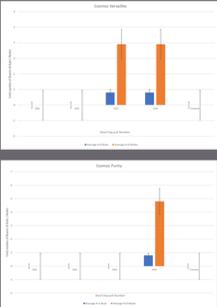
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0 5 10 15 20 25 30
Number of Short-Days

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.

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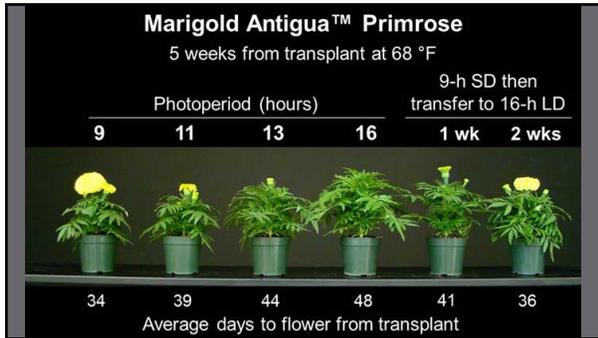
Conclusion: Cosmos are induced to set bud in as little 3 short-days. For this reason, cosmos should always be placed under night interruption lighting when first received and unloaded from a truck Often material is not planted for 3-4 days after unloading. . . . This is long enough to cause premature flowering in early spring (earlier than March 21).

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Plants that require LD for 2–3 weeks after germ to bulk:

- Cosmos
- Zinnia
- Gomphrena
- African Marigold
- Celosia
- Mina Vine
- Morning Glory

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Early in spring (before March 21) some crops must receive long-days (NI-lighting) to keep plants actively growing - short-days will promote tuber formation.



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Plants that require LD after germ to bulk and inhibit tubers/storage roots:

- Dahlias
- Tuberous Begonias
- Ipomea
- Asparagus Fern
- Some Salvia (Salvia patens)
- Asclepias

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From March 1 until October 1, a number of LD crops, require short days (8-10 hours) in order to bulk plants.



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Plants that may require SD after germ to bulk and inhibit flowering:

- Fuchsia
- Rudbeckia
- Lobelia
- Dill
- Oregano
- Thyme
- Snapdragons
- Dianthus
- Pansy



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Examples

- Cosmos (assume 4 week plug and 6 week finish in a quart. . . .)
- Blue Lobelia (assume 6 week plug and 4 week finish in a 1206 pack). . . .
- First 4 weeks, then 6 weeks short days.
- 5 weeks short days, then 5 long days

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Remember to Unfold Enough Leaves on Seed Propagated Perennials Before Induction!

Plant Species	Minimum Leaf Number
<i>Aquilegia</i> 'McKana's Giant'	12 nodes
<i>Aquilegia</i> 'Fairyland'	15 nodes
<i>Coreopsis grandiflora</i> 'Sunray'	8 nodes
<i>Gaillardia x grandiflora</i> 'Goblin'	16 nodes
<i>Heuchera sanguinea</i> 'Bressingham'	19 nodes
<i>Lavandula angustifolia</i> 'Munstead'	18 nodes
<i>Rudbeckia fulgida</i> 'Goldstrum'	10 nodes

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Scheduling Flowering

- General Concepts: Flowering and Development Rate
- Seed Propagated Flowering Plants
- Asexually Propagated Plants (Cuttings, Division, Tissue Culture)




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Vegetative Annuals and Perennials

Vegetative Annuals

- Cuttings often arrive flowering and can be difficult to stop from flowering.
- Therefore, we inhibit flowering of vegetative annuals by applying regular (2-4 week) applications of low rate Florel (200-250 ppm).

Vegetative Perennials

- Generally, we inhibit flowering on perennials by growing plants under non-inductive conditions (>63 °F and/or SD).

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Marigold

Fast-drying
(86 F/ 45% RH)

Slow-drying
(59 F/ 85% RH)

0 ppm 600 ppm



71

Example

- Fuchsia basket (5 cuttings in a 10" basket).



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Florel vs Configure

<p>Florel</p> <ul style="list-style-type: none"> • Aborts flowers- delays flowering 5 weeks. • Increases branch number • Reduces leaf size • Reduces elongation • 48 hr REI • Produces ethylene • Efficacy increases with drying time 	<p>Configure</p> <ul style="list-style-type: none"> • Increases branch number • Reduces elongation • Reduces rooting • Delays flowering 2-4 days • 12 hr REI • Is a cytokinin (benzyl-adenine) • Efficacy increases with drying time
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Configure can be added to the production schedule to reduce labor and/or crop timing.

No Florel – Configure x 2 (200 ppm)

Previous: Florel x 2 (500 ppm)



Now: Florel (500 ppm) then Configure (200 ppm) = 2-3 week reduction in crop timing



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Petunia	Florel	Configure	Cycocel	B-9	Bonzi	A-Rest	Control
Florel							
Configure							
Cycocel							
B-9							
Bonzi							
A-Rest							
Control							

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Perennials



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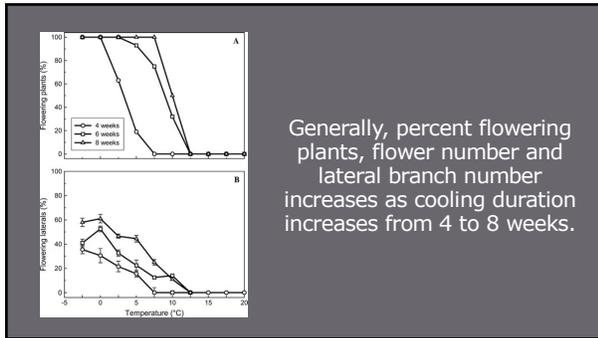
<p>Category 1 - No Cold Required - Flowers from plug in 8 weeks or less - Day-neutral and long day plants</p> <table border="1" style="width: 100%;"> <tr> <th>SEED</th> <th>VEGETATIVE</th> </tr> <tr> <td>LD ADYNIA LD EUPHORBIA LD CYPREP LD DIPLO LD PENT LD SILV</td> <td>LD ADYNIA LD EUPHORBIA LD CYPREP LD DIPLO LD PENT LD SILV</td> </tr> </table>	SEED	VEGETATIVE	LD ADYNIA LD EUPHORBIA LD CYPREP LD DIPLO LD PENT LD SILV	LD ADYNIA LD EUPHORBIA LD CYPREP LD DIPLO LD PENT LD SILV	<p>Category 2 - No Cold Required - Flowers from plug in 8 weeks or more - Day-neutral and long day plants</p> <table border="1" style="width: 100%;"> <tr> <th>SEED</th> <th>VEGETATIVE</th> </tr> <tr> <td>LD ADYNIA LD EUPHORBIA LD CYPREP LD DIPLO LD PENT LD SILV</td> <td>LD ADYNIA LD EUPHORBIA LD CYPREP LD DIPLO LD PENT LD SILV</td> </tr> </table>	SEED	VEGETATIVE	LD ADYNIA LD EUPHORBIA LD CYPREP LD DIPLO LD PENT LD SILV	LD ADYNIA LD EUPHORBIA LD CYPREP LD DIPLO LD PENT LD SILV
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LD ADYNIA LD EUPHORBIA LD CYPREP LD DIPLO LD PENT LD SILV	LD ADYNIA LD EUPHORBIA LD CYPREP LD DIPLO LD PENT LD SILV								
<p>Category 3 - No Cold Required - Flowers from plug in 8 weeks or more - Short day plants</p> <table border="1" style="width: 100%;"> <tr> <th>SEED</th> <th>VEGETATIVE</th> </tr> <tr> <td>LD-SD SILV</td> <td>LD-SD ADYNIA LD-SD EUPHORBIA LD-SD CYPREP LD-SD DIPLO LD-SD PENT LD-SD SILV</td> </tr> </table>	SEED	VEGETATIVE	LD-SD SILV	LD-SD ADYNIA LD-SD EUPHORBIA LD-SD CYPREP LD-SD DIPLO LD-SD PENT LD-SD SILV					
SEED	VEGETATIVE								
LD-SD SILV	LD-SD ADYNIA LD-SD EUPHORBIA LD-SD CYPREP LD-SD DIPLO LD-SD PENT LD-SD SILV								

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Many perennials benefit from a cold treatment.

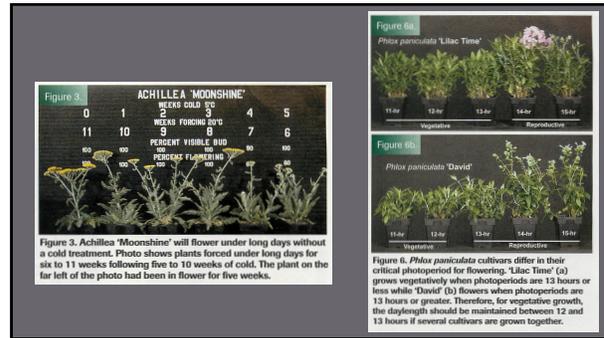
Suppliers have been working to breed 'non-cold requiring' perennials. . .

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Generally, percent flowering plants, flower number and lateral branch number increases as cooling duration increases from 4 to 8 weeks.



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Table 1. Stage Of Production

Species	Temp. (°F)	Stock Plants	Propagation	Bulking	Cooling	Forcing	Total
Achillea 'Moonshine'	Weeks --	64-68	73-77	65-70	35-41	68	12
Gaura lindheimeri	Weeks --	3	3	3	0	6	12
Phlox paniculata	Weeks --	12-13	3	3	0-5	10-11	16-22

LD = Long days, ≥ 14 hours or Night Interruption ND = Natural days

Table 1. Recommended temperatures and photoperiods and minimum production durations (in weeks) for five-inch flowering pot plant production.

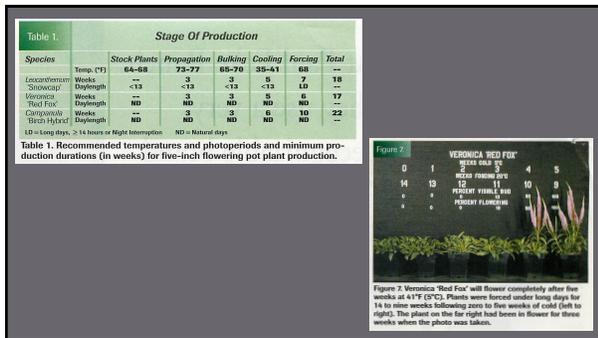
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Table 1. Recommended temperatures and photoperiods and minimum production durations (in weeks) for five-inch flowering pot plant production.

Table 1. Columbine tables - cultivars we have studied in our research program.

Cultivar	Description	Height	Leaf # before cold	Weeks of cold (41°F)	Special considerations for flowering
Aquilegia 'Avalanche'	Very compact	8.5"	35	0	Flowers mostly, even without cold. Strong, well-balanced flowers in 8" round flower. Very dry first budset.
Aquilegia 'Avalanche'	Very compact, dark red to red flowers	8.5"	7.0	0	Single bud set in 10" round flower. Very dry first budset. Best performance in 10" round flower.
Aquilegia 'Avalanche'	Single bud set in 10" round flower	13-16"	12-10	0	Best to transition and bulk 4 weeks after cold treatment - when 1 bud set. 10" round flower.
Aquilegia 'Avalanche'	Single bud set in 10" round flower	14-21"	212	0	Performance improved when colded in 10" round flower.
Aquilegia 'Avalanche'	Large shrubby flower in 10" round flower	14-21"	7.0	0	Best performance - 10" round flower. Very dry first bud set. Best performance in 10" round flower.
Aquilegia 'Avalanche'	Large shrubby flower in 10" round flower	20-24"	12-14	0	Performance improved when colded in 10" round flower.
Aquilegia 'Avalanche'	Large shrubby flower in 10" round flower	12-14"	12-14	0	Performance improved when colded in 10" round flower.
Aquilegia 'Avalanche'	Large shrubby flower in 10" round flower	11-13"	8-10	10	Single bud set in 10" round flower. Best performance in 10" round flower.
Aquilegia 'Avalanche'	Large shrubby flower in 10" round flower	12-14"	214	10	Single bud set in 10" round flower. Best performance in 10" round flower.
Aquilegia 'Avalanche'	Large shrubby flower in 10" round flower	15-21"	212	212	Single bud set in 10" round flower. Best performance in 10" round flower.

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Special Consideration

- Creeping Phlox – generally plants September 1 – October 1. Planting earlier in warm climates can result in weak establishment.
- Iberis – generally plant September 15 – October 15. Planting earlier in warmer climates can result in weak growth.
- Hosta – generally plant 2–3 eye plants September 1 – October 1 to establish and increase eyes (shoots) to 4–5.

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Other Work



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Transformation, CRISPR and Mutagenesis Center Focusing on ornamentals and vegetable

Yiping Qi



CRISPR

VJ Tiwari



Double Haploid

Gary Coleman



Tissue Culture and Mutagenesis

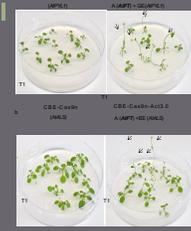
Nidhi Rawat



Disease Resistance

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Speed Breeding

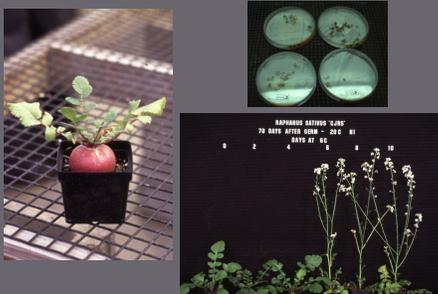


FT can be permanently 'turned on' to have early and continuous flowering.

— Does this have any application in floriculture?
Are continuously flowering photoperiodic plants desirable?

(Pan et al., Nature Plants (2020) 10:1–10, Nature Biotechnology 2019)

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Engelen-Egles, G., and Erwin, J.E. 1997. A new model plant for vernalization studies. *Scient. Hort.*, 70:197–202.

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