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Fundamentals of Flowering in Plants:
Juvenility in Seed-Propagated Annuals and How Supplemental Lighting Can Affect It

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Part I

Introduction:

This article is the first of a series presenting new research results on effects of daylength and supplemental lighting on flowering of seed-propagated bedding plants that we are conducting at the University of Minnesota. This project started years ago when a greenhouse grower called and wanted to know how to have flowering petunias during February and March in the Seattle area. A couple of months after that I was asked how to delay flowering in summer germinated pansies in Minnesota for sales in Texas in the late summer and fall. The answers were not 'clear cut' and we realized how little we know about what causes flowering in common bedding plants. The last time a series of experiments was done to really look at what causes bedding plants to flower was done during the late 1950's and early 1960's!

Information on what makes bedding plants flower would allow you to control flowering to schedule flowering accurately as we do with many potted plant crops such as chrysanthemum and poinsettia. Because we didn't have the answers for these growers and the importance of this information to the North American greenhouse industry, we started a long-term research study examining how daylength, supplemental lighting and temperature affect flowering of many bedding plant species and how to precisely control flowering of bedding plants.

This article and the next will focus on how light intensity, or irradiance, affects flowering of bedding plant species. The following articles will show how daylength affects flowering of common and uncommon bedding plants. The results were interesting to us and have a tremendous amount of application for the industry (especially those who grow bedding plants from seed).

INSIDE THIS ISSUE:

Juvenility versus Maturity:

Plant flowering is controlled by internal and external signals. With any seed-propagated bedding plant there is an internal signal that determines when a plant is mature and capable of flowering or responding to a flowering stimulus such as daylength. For instance, there is a period with animals after birth when they are incapable of reproducing. Similarly, plants are often unable to flower immediately after germinating. The period after germination when a seedling is not capable of flowering or responding to a flowering stimulus is called the 'juvenile period'. When a seedling is capable of responding to a flowering stimulus we say it is 'mature'.

How do we know when a seedling has changed from the juvenile to the mature phase? Unfortunately, with most seed-propagated annuals, there is no visible change in how the plant looks when it changes from a juvenile to a mature plant. Probably the best indicator we have is the number of leaves that a plant has.

Much work has been conducted using leaf number as a measure of plant age. Fortunately, we find that the leaf number when a plant changes from a juvenile to an adult plant can be the same over time but will change with the

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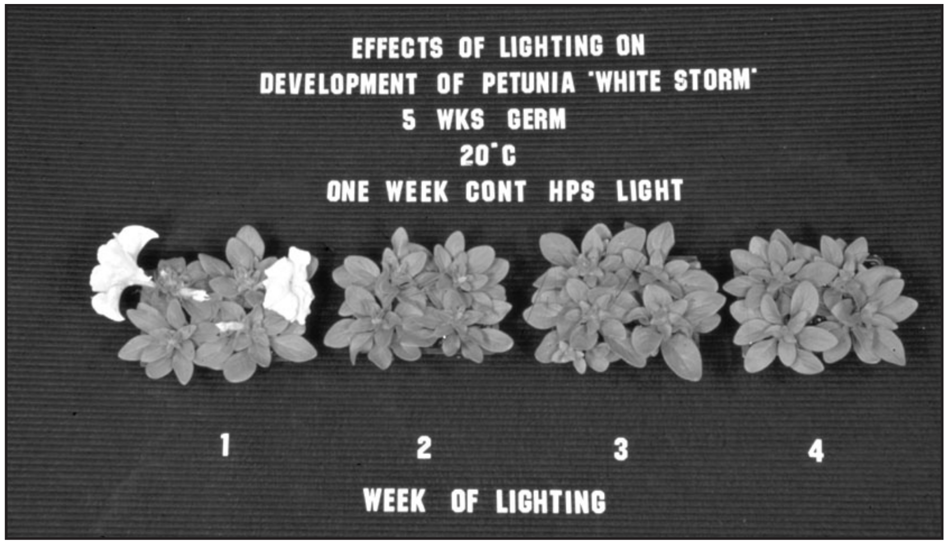
species and environment. Recent articles on perennials by researchers at Michigan State University have shown that seed-propagated perennials must have a certain number of leaves on a plant before they are able to respond to a cooling treatment (vernalization) which is necessary for flowering with many perennials. The same is the case for many seed-propagated annuals; they must have a certain number of leaves before they can respond to an external treatment.

Breeding of seed-propagated flowering crops has emphasized earliness of flowering over the years to reduce the time to flower. Reduced time to flower means reduced production costs to the grower. Because of this, there has been progressive selection for reduced juvenile period length by breeding companies. In other words, many of the traditional bedding plants have few leaves they must unfold when they change from juvenile to adult plants and can flower.

For this reason, many traditional types of bedding plants need to unfold few leaves before they can sense a stimulus. Often new types of bedding plants such as violas, and Wave type petunias have not been heavily bred and can have a longer juvenile period. For instance, the new petunia type 'Purple Wave' is much closer to the wild germplasm and has a longer juvenile period. Note in Figure 1 that the plants did not perceive the 1 week of long-days (stimulates flowering in petunia) until after 2 weeks, i.e. Purple Wave petunia has a juvenile period that lasts about 2 weeks compared to the very short juvenile period for 'White Storm.'



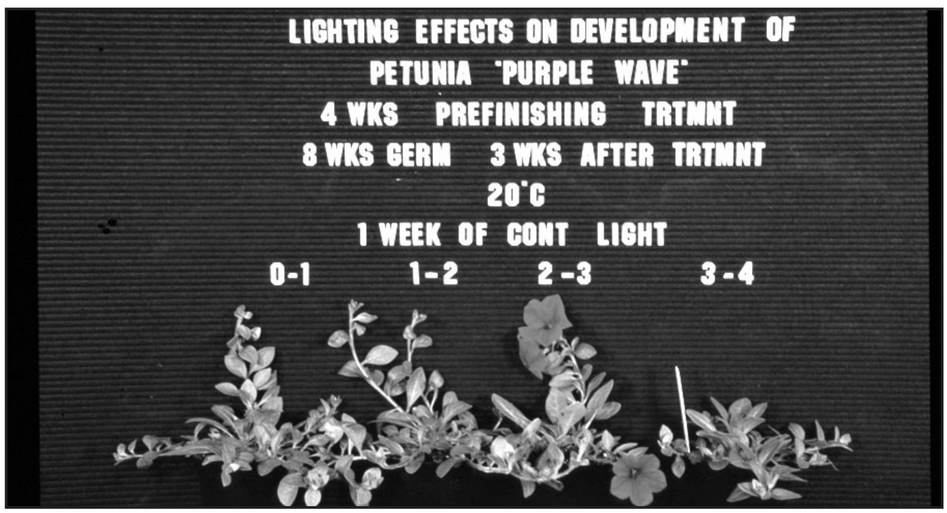


Figure 1a and b. The effect of providing a single week of continuous lighting (long-days induce flowering in petunia) to Petunia x hybrida 'White Storm' (a) and Purple Wave (b). Note that White Storm was sensitive to getting the single week of continuous lighting during the first week (week 0-1) and Purple Wave was not sensitive to the week of continuous lighting until weeks 2-3. This showed that the juvenile period for White Storm is less than that for Purple Wave.

Light Intensity (Irradiance) Affects Earliness of Flowering:

Many environmental factors affect how long the juvenile period is in seed-propagated plants. Perhaps the most important environmental factor that affects juvenile period length is light. When we talk about light, we can talk about light color (light quality), duration (photoperiod or daylength), light intensity (irradiance), or total amount per day (light integral). Here, I am going to be talking about primarily light intensity and amount of light per day (irradiance and light integral). Together, these two light factors quantify how much light is available for photosynthesis instantaneously (irradiance) or over a 24 hour period (light integral).

We have known for some time that the amount of light a plant gets per day (light integral) affects how soon some seed-propagated annuals flower. For instance, there is a 'rule-of-thumb' that every day that you provide supplemental lighting to a seed geranium crop early after germination reduces time to flower by one day. There has been incredibly little information on how supplemental lighting affects flowering of other bedding plant species even though plug growers

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commonly use supplemental lighting to improve plug quality. Often this supplemental lighting does increase plant mass – which is a determinant of plant quality – but we do not know the ultimate effect of these lights on flowering. I think that some growers just assume that adding lights results in earlier flower. This is not the case for some crops!

Because there is no term to describe how irradiance or light integral affects flowering, we made two new terms to describe these two responses: facultative irradiance and irradiance indifferent response groups.

1) When a plant has a **facultative irradiance response**, extra lighting reduces the leaf number below the first flower, i.e. flowering occurs earlier developmentally.
2) When a plant has an **irradiance indifferent response**, extra lighting has no effect on the leaf number below the first flower, i.e. extra lighting does not hasten flowering developmentally.

There is some confusion with how lighting affects earliness in flowering with many crops. Remember that when you add lights, you heat the plants because of the infra-red light emitted by most lamps. With many plants the earlier flowering after adding lights is simply because plants are warmer and grow faster, and therefore, flower earlier. This can be the case with earlier flowering after adding lights over irradiance indifferent plants where leaf number below the flower is unaffected. For instance, in Figure 2 a and b you can see that although leaf number was not greatly affected by adding supplemental lighting, time to flower decreased on the irradiance indifferent plants Black-Eyed-Susan Vine (Thunbergia) and Mexican Sunflower (Tithonia) as light intensity increased from 0 to +150 *u*mol m^{-2} s^{-1} (+750 footcandles) supplemental high pressure sodium lighting. In contrast, with facultative irradiance plants, plants flower much quicker because they have fewer leaves below the flower **and** they are growing faster (leaves unfolding faster) because of heating from the lamps. For instance, in Figure 2 a and b you can see that time to flower was decreased from 78 to 57 days and 92 to 75 days on the facultative irradiance response plants Sweet Pea (Lathyrus) and Tweedia as light intensity increased from 0 to +150 *u*mol m^{-2} s^{-1} (+750 footcandles) supplemental high pressure sodium lighting.

In most cases, heating with lamps is pretty expensive and not a very cost efficient way to speed up plant development! Therefore, unless you need more plant mass on a seedling it may not be economical to add supplemental lighting to irradiance indifferent bedding plant seedlings.

Table I shows what irradiance response group many bedding plants

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Table 1. Lighting classification of different seed-propagated bedding plant species with respect to flowering.

Facultative Irradiance Response	Irradiance Indifferent Response
Catananche caerula 'Blue' (Catananche)	*Ageratum houstonianum* 'Blue Danube' (Ageratum)
Lathyrus odoratus 'Royal White' (Sweet Pea)	*Amaranthus hybridus* 'Pygmy Torch' (Amaranthus)
Linum perenne (Flax)	*Ammi majus* (Ammi)
Tweedia caerula 'Blue Star' (Tweedia)	*Asperula arvensis* 'Blue Mist' (Asperula)
Convolvulus tricolor 'Blue Enchantment' (Dwarf Morning Glory)	*Centaurea cyanus* 'Blue Boy' (Bachelor's Buttons)
Cosmos bipinnatus 'White Sensation' (Cosmos)	*Cobea scandens* 'White' (Cup and Saucer Vine)
Gazania rigens 'Daybreak Red Stripe' (Gazania)	*Collinsia heterophylla* (Collinsia)
Limnanthes douglasii (Fried Eggs, Meadow Foam)	*Dolichos lablab* (Hyacinth Bean Vine)
Nemophila maculata 'Pennie Black' (Five-spot)	*Eschscholzia californica* 'Sundew' (California poppy)
Nicotiana alata 'Domino White' (Flowering Tobacco)	*Ipomopsis rubra* 'Hummingbird Mix' (Standing Cypress)
Origanum vulgare (Oregano)	*Limonium sinuata* 'Heavenly Blue' (Statice)
Silene armeria (Sweet William Catchfly)	*Mathiola longipetala* 'Starlight Scentsation' (Stock)
	Mina lobata (Mina Vine)
	Oenothera pallida 'Wedding Bells' (Sundrops)
	Phacelia campanularia (California Bluebell)
	Sanvitalia procumbens (Creeping Zinnia)
	Thunbergia alata (Black-Eyed-Susan Vine)
	Tithonia rotundifolia 'Sundance' (Mexican Sunflower)

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fit into. The next article will have a similar table with many more bedding plants that we have studied. With irradiance indifferent plants, extra lighting did not affect leaf number below the flower. In contrast, with facultative irradiance group plants, extra lighting reduced the leaf number below the first flower on these plants which reduced the time to flower dramatically.

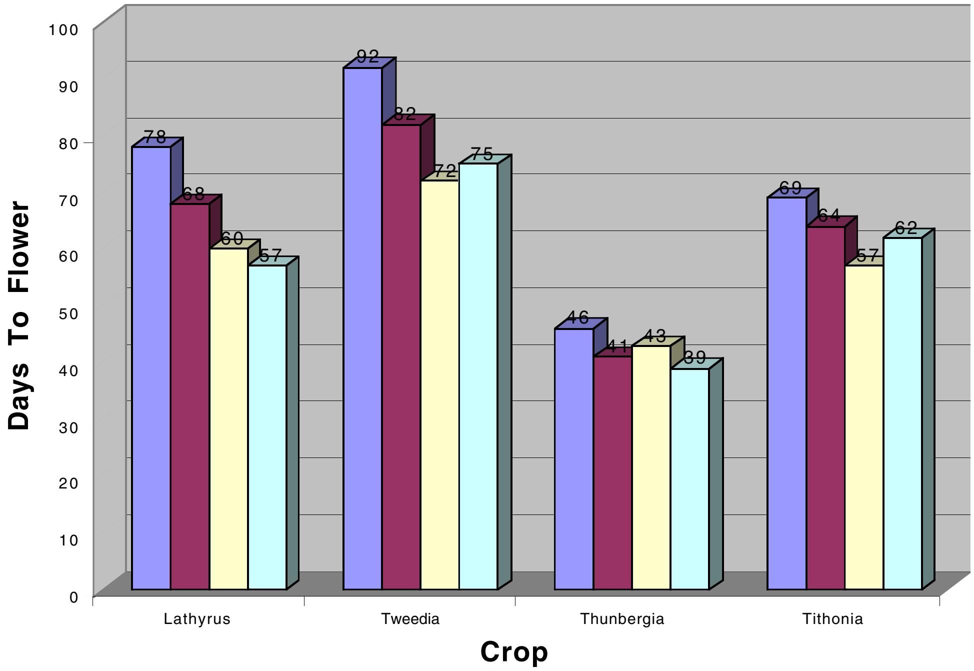

Figure 2a and b. The effect of increasing irradiance (light intensity) from 0 to +150 *u*mol m^{-2} s^{-1} (+750 footcandles) supplemental high pressure sodium lighting on time to flower (a) and leaf number below the first flower (b) of the facultative irradiance response plants Sweet Pea (Lathyrus) and Tweedia and the irradiance indifferent plants (Black-Eyed-Susan Vine (Thunbergia) and Mexican Sunflower (Tithonia). Ambient light integral (day light) was 12-13 moles per day with an average irradiance (light intensity) of 500-606 umol m^{-2} s^{-1} (2,500-3030 footcandles) during the course of this experiment.

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