Vernalization: Life In The Cold

In the second article of our series on perennial vernalization, Michigan State University researchers share the tricks of the trade.

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IN the first article (October GG 2005, page 38), we introduced the topic of vernalization, the "chilling requirement" needed for flowering of many but not all herbaceous perennials.Sometimes the vernalization requirement is obligate (a cold period is absolutely required, plants will not flower without cold) but often is facultative (a cold period is merely beneficial, plants benefit from but do not require a cold treatment). In this article we describe the practical aspects of vernalization and how to properly vernalize cold-requiring perennials.

Juvenility Issues And Vernalization

• Are your plants old enough to flower? Many perennials can be started as small plants (from 128- or 72-cell plugs) and will flower readily if exposed to environmental conditions that promote flowering such as photoperiod or vernalization. Other perennials must pass through a juvenile stage and reach adequate maturity (a certain age or size) before they will flower. Juvenility is defined as the "early phase of growth during which flowering cannot be induced by any treatment." In some cases, perennials with a juvenility requirement have an additional vernalization and/or photoperiodic requirement for flowering. It is therefore important to ensure that plants are mature prior to the chilling or photoperiod treatment because young, immature plants will not flower.

• Which perennial species have a juvenility requirement for flowering and when do they become mature? We have listed a few perennial species with known juvenility issues in Table 1. We have primarily found juvenility to be an issue in the production of a number of seed-propagated late-spring and early-summer flowering species such as columbine (aquilegia), cushion spurge (Euphorbia epithymoides), coral bells (heuchera) and lady's mantle (Alchemilla mollis), to name a few. Juvenility can also be an issue in vegetatively propagated perennials such as bugleweed (ajuga), pulmonaria and heuchera.

As plants develop and gradually mature, they become more sensitive to environmental conditions that promote flowering until juvenility is lost. Depending on species, and sometimes cultivar, the juvenile stage can last from a few days to several weeks or longer. For example, heuchera 'Bressingham Hybrids' has a juvenility requirement and also requires 10 weeks of cold for flowering. Small plugs with six to seven leaves were considered juvenile prior to the cold treatment and these plants failed to flower. Larger plugs with 13 to 17 leaves were mature and of ample size to flower following the chilling treatment (Figure 1A, B). In subsequent studies,

Figure 1A. Heuchera 'Bressingham Hybrids' requires 10 weeks vernalization at 41°F for flowering. Noncooled plants do not flower.
Figure 1B. 'Bressingham Hybrids' plants required a minimum of eight to 11 nodes before the chilling treatment for flowering. 128-cell plugs with six to seven leaves were juvenile and failed to flower after 10 weeks of cold. Larger 50-cell plugs with 13 to 17 leaves were mature and flowered following the chilling treatment.

Figure 2A and B. Juvenility requirements vary with perennial species, and in some cases cultivar within a species. Alchemilla mollis required eight weeks of bulking under short days followed by nine weeks of vernalization at 41°F for complete flowering while Euphorbia epithymoides plants of a similar size and given the same treatment failed to flower.

we found that heuchera 'Bressingham Hybrids' seedlings required a minimum of eight to 11 nodes before the chilling treatment for flowering.

Determining Plant Age

How do we know when a plant has reached adequate maturity and is capable of flowering? Empirical methods to quantify plant size, such as counting leaf or node numbers or measuring crown diameter, can be used to determine whether plants have passed the juvenile stage, but it is also important to note that these methods are not exact and will vary with environmental conditions such as greenhouse temperature and light levels. Unfortunately, there is generally no visible sign (or as yet chemical sign) that readily distinguishes a plant as mature.

Overcoming Juvenility

Crops that have a juvenile phase must be grown on and bulked until mature before they can be cooled. Providing a cold treatment to immature plants may be effective if the cold treatment is given in greenhouses or in chambers with sufficient light to promote some growth during the cold treatment. In fact, we have found that perennials such as veronica and isotoma continue to develop when chilled in lighted chambers at temperatures above 28°F. In this case, the shift from juvenile to adult occurs while the plants are growing at the low temperatures. In some cases, commercial growers choose to transplant perennials into larger containers in the fall and overwinter them for next year's sales. This generally provides ample time for bulking prior to and during the cold treatment.

The amount of additional growth required before plants can be properly vernalized depends on species, initial plant size, greenhouse temperature and light levels. Detailed studies determining the exact leaf number required to reach maturity are lacking for most perennials. Though it is difficult to say with certainty, we often suggest bulking perennials with a juvenility requirement for an additional four to eight weeks before cooling, though this may or may not work for all the species listed in Table 1. For example, we found that alchemilla plugs with five to six leaves required eight weeks of bulking followed by nine weeks of cooling at 41°F for complete flowering, while Euphorbia epithymoides plugs of a similar size failed to flower when given these same treatments (Figure 2A, B).

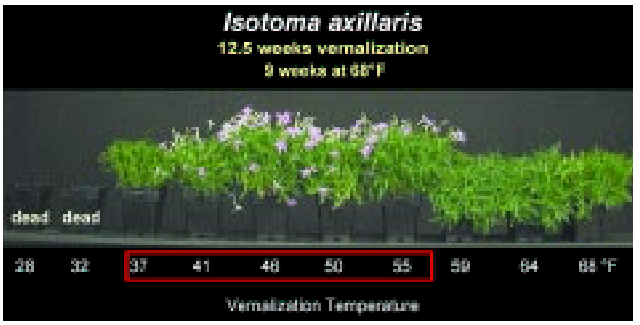

Figure 3. The majority of perennials such as isotoma can be vernalized at temperatures below 60°F for a minimum of five to six weeks. Complete flowering of Isotoma axillaris occurred following 12 ½ weeks of chilling at 37°F to 55°F (denoted by red box). Caution must be used when vernalizing tender plants like isotoma, and growers must ensure that plants are properly hardened off before chilling at temperatures below 36ºF or plant death may result.

What Is Meant By "Cold" And How Much Is Needed?

• Vernalization temperature and duration. Vernalization has been studied for nearly a hundred years. Interestingly, temperatures of 32°F to 60°F have been documented as effective for vernalizing a wide range of plant species from agronomic crops such as wheat and rye to vegetable crops such as carrot and onion. While we generally recommend vernalizing herbaceous perennials at 37°F to 46°F for up to 15 weeks, depending on species, only a few comprehensive vernalization studies have been conducted on cold-requiring perennial species. We set out to determine the most effective temperatures that could be used to vernalize a number of diverse herbaceous perennials and evaluated flowering responses of veronica, isotoma, campanula and dianthus to temperatures of 28°F to 68°F.

In our vernalization trials, we found that all species could be effectively vernalized at temperatures of 41°F to 46°F for four to six weeks, although this was not necessarily the optimum temperature or required duration for maximum flowering. None of the perennial species flowered if vernalized at or above 60°F (Figure 3). As plants were cooled for longer periods at each temperature, the intensity of the vernalization response increased and was characterized by increased flowering percentage, reduced time to flower and/or a greater number of flowers per plant. This can readily be seen with veronica 'Red Fox' where more flowering shoots formed on plants that were chilled for longer periods. Thus, it is difficult to target an optimum vernalization temperature and duration that will ultimately depend on the intensity of the desired flowering response.

How low can you go? Growers must exercise some caution when cooling plants at or below freezing temperatures. Tender plants such as isotoma that have not been properly hardened off before chilling may fail to vernalize or even die as a result (Figure 3). Some herbaceous perennials benefit from hardening of plugs at 32°F to 41°F for several weeks before vernalization. Pretreatment for two to six weeks at 41°F markedly improved survival and regrowth for a range of herbaceous perennial seedlings grown in plug trays including aquilegia, astilbe, leucanthemum, echinacea, gaillardia, iberis and rudbeckia.

Chilling Techniques

Container size can make a difference. Many perennials such as vampanula and figitalis can be cooled directly in the plug tray while others are more appropriately transplanted and cooled in the finished container. For example, flowering percentage of Aquilegia chrysantha improved when plugs were transplanted into 5-inch containers before receiving nine weeks of chilling at 41°F (Figure 4). Plugs that were directly cooled in the tray then transplanted to the finished container had lower flowering percentages. Other columbines such as 'Mini Star' and 'Cameo' have essentially no juvenility requirement and can be cooled directly in the plug tray as small seedlings. However, these cultivars do benefit from a bulking treatment that improves overall plant size in the container after cooling. A number of perennials that are appropriate for each method of cooling are listed in Table 1.

Cold Delivery

In northern climates such as Michigan, plants can generally be cooled in unheated or minimally heated greenhouses with minimum temperatures of 28°F. However, maintaining cool temperatures is very difficult on sunny days during the onset of spring. We have encountered problems with insufficiently vernalized plants and there is a good chance that this was a result of warm days during the early spring. In some regions of the country, plants can be overwintered naturally outdoors and protected with frost cloth when temperatures fall below freezing. In mild climates, natural winter temperatures may not adequately vernalize cold-requiring perennials, and some Southern growers have vernalized perennial crops in lighted coolers. In these instances, plants are more effectively cooled in controlled environment chambers or refrigerated reefers that allow for precise temperature control and delivery compared to outdoor conditions. Other benefits to controlled environment chilling include the potential for year-round cooling and the ability to cool plants directly in plug trays, thereby increasing the number of plants that can be vernalized per square foot.

Light During Vernalization

Many perennials that are harvested as bareroot material can be effectively stored in the dark, primarily because they have adequate carbohydrate reserves in their crown and root systems to see them through the "winter." Smaller plants that maintain their foliage during the chilling treatment do not have substantial biomass as their bareroot counterparts must be stored in a lighted cooler or overwintered in an unheated structure with natural light. Although plant growth is visibly reduced at low, chilling temperatures, we know that many species continue to develop root systems and some shoot growth occurs even at near freezing temperatures (see Figure 2). Therefore, plants need to be provided with minimal amounts of light for photosynthesis to sustain them through the chilling treatment.

We have found that the majority of perennials can be effectively chilled in environmentally controlled chambers set at 28°F to 41°F when provided with nine hours of light (25 to 50 footcandles) from cool-white fluorescent bulbs. For the majority of perennials we have studied, this amount of light has been adequate to keep plants alive for up to 15 weeks, and in some cases longer. As cooling temperature increases, plants require more light to support photosynthesis and sustain them as they grow. We found that some perennials such as isotoma and veronica can be cooled for up to 15 weeks at 46°F to 68°F when provided with 500 footcandles of light. At 28°F, plants may be held in the dark, but as discussed above, the majority must first be hardened.

Not all perennials maintain their foliage during the chilling treatment and in many cases, the foliage may die back completely. Do not be alarmed, plants will resume visible growth once returned to warmer temperatures.

General Plant Care

It is important to keep plants hydrated during the chilling treatment, although overwatering can lead to serious problems. Botrytis is often encountered in dimly lit chilling environments, especially on perennials that maintain their foliage throughout the winter. Overhead irrigation of plants in these cool environments leads to wet foliage and greater disease incidence. When possible, subirrigate plug trays or containers to prevent wetting of the foliage and treat all plants with a fungicide prior to chilling. If growers are holding plants at 28°F, it may be best to protect them from desiccation using plastic barriers. Clear, low-density polyethylene can work well since it is transparent, robust and an excellent barrier to water movement.

Figure 4. Aquilegia chrysantha plugs that were directly cooled in the plug tray had lower flowering percentages than those that were transplanted to the finished container before receiving the nine-week chilling treatment

The remaining articles in this series will address specific vernalization responses of herbaceous perennials with photoperiodic requirements for flowering, as well as identify how photoperiod and light quantity can partially or fully substitute for the vernalization requirement in a wide range of perennial species. GG

Left: Perennials overwinted outdoors are covered with frost cloth when temperatures dip below freezing. Below: Lavandula plugs can be naturally cooled in a minimally heated greenhouse in winter months.

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To see the complete first article, go to www.

greenhousegrower.com/grower_tools and click on "Perennials."

Table 1.

Cold-requiring perennials that can be cooled directly in the plug tray. No known juvenility issues.

- Brunnera macrophylla
- Campanula garganica
- Campanula portenschlagiana
- Campanula 'Birch Hybrid'
- Coreopsis grandiflora 'Baby Sun' and 'Sunray'
- Corydalis lutea
- Delasperma cooperi
- Digitalis thapsi 'Spanish Peaks'
- Digitalis purpurea 'Foxy'
- Erigeron 'Prosperity'
- Isotoma axillaris
- Leucanthemum species and cultivars
- Lobelia x speciosa 'Compliment Scarlet'
- Lychnis flos-cuculi 'Jenny'
- Oenothera fructicosa
- Penstemon species and cultivars
- Veronica spicata 'Red Fox' and 'Goodness Grows'

Cold-requiring perennials that benefit from bulking in a larger container before chilling. Juvenility can be a problem, especially when cooled as small plugs.

- Ajuga cultivars
- Alchemilla mollis
- Aquilegia 'Origami Blue'
- Aquilegia flabellata 'Cameo' and 'Mini Star'
- Aquilegia x hybrida 'Crimson Star,' Musik and Songbird series
- Armeria maritima
- Astilbe chinensis pumila
- Astilbe x hybrida
- Campanula 'Kent Belle'
- Campanula punctata 'Cherry Bells'
- Dianthus deltoides
- Dianthus gratianopolitanus 'Bath's Pink' and 'Firewitch'
- Dicentra 'Luxuriant'
- Digitalis obscura
- Euphorbia amygdaloides 'Purpurea'
- Euphorbia epithymoides (polychroma)
- Gaillardia x grandiflora 'Baby Cole' and 'Goblin'
- Geranium dalmaticum
- Geranium sanquineum 'New Hampshire Purple'
- Heuchera species and cultivars
- Heucherella species and cultivars
- Iberis sempervirens
- Lavandula angustifolia cultivars
- Lewisia cotyledon
- Linum perenne
- Phlox divaricata
- Phlox subulata
- Physostegia virginiana
- Pulmonaria species and cultivars
- Saxifraga species and cultivars
- Stokesia laevis
- Tanacetum 'Jackpot'
- Thalictrum kuisianum
- Thymus serphyllum

Cold-requiring perennials that need extensive bulking in the final container before chilling. These generally have significant juvenility issues and must have large starting material for flowering. While these are just a few examples, many larger perennials fall into this category.

- Amsonia
- Aquilegia some species and older cultivars
- Baptisia australis
- Cimicifuga racemosa
- Hosta species and cultivars
- Rodgersia aesculifolia
- Thalictrum aquilegifolium