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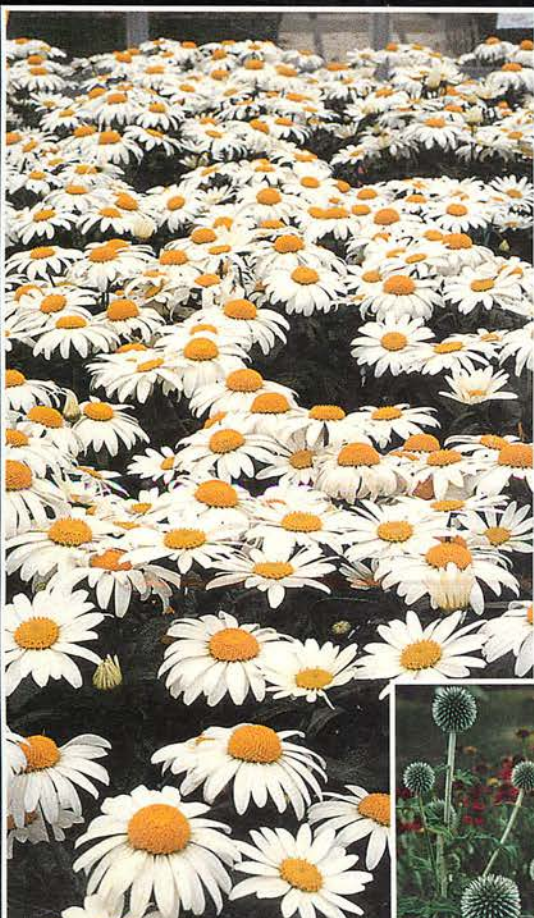

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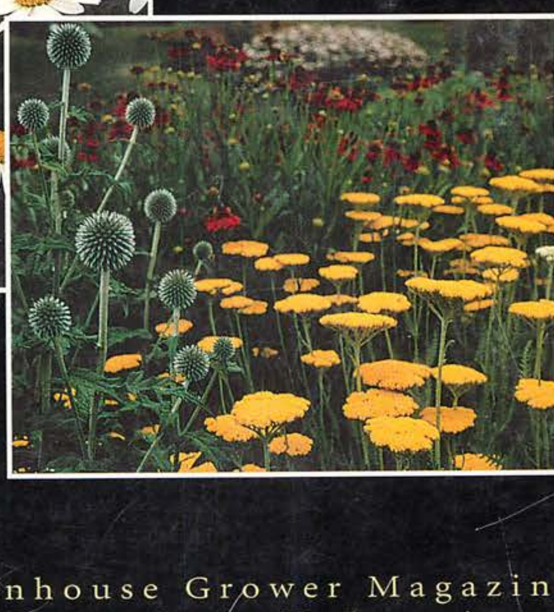

From Greenhouse Grower Magazine and Michigan State University






GREENHOUSE GROWER and Michigan State University researchers have teamed up to compile all three Forcing Perennials series into one booklet, In **Firing Up Perennials: The 2000 Series,** *we've included all 35 Forcing Perennials articles that have appeared in GREENHOUSE GROWER since March 1996. As a bonus, we've included an additional article on producing the tender perennial* **Pennisetum setaceum,** *or purple fountain grass, and an introductory article summarizing MSU's perennial research efforts.*

Firing Up Perennials: The 2000 Series *has been reorganized for your convenience. We've made this booklet easy for you to use, grouping together topical articles and alphabetizing perennials by species name.*

We hope this booklet will be a valuable tool for your greenhouse operation. Good luck and great growing!

-GG staff and MSU researchers

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Forcing Perennials For Flowering Potted Crops

by **ERIK S. RUNKLE, BRIDGET BEHE, ART CAMERON, WILL CARLSON,** and **ROYAL D. HEINS**

HERBACEOUS perennials comprise a vast array of species and cultivars that flower naturally from early spring to late autumn. Commercial U.S. growers have traditionally produced nonflowering perennials. Interest in producing flowering perennials has increased in recent years because flowering plants outsell nonflowering ones in most instances. But there's relatively little information available on how to flower perennials, making uniform and timely crop flowering difficult.

Since 1993, one of the major research objectives of the floriculture program at Michigan State University (MSU) is to identify flowering requirements for a broad range of cold-hardy (to about –20°F) herbaceous perennials so that crops in flower and of a certain height are ready for sale on a predetermined date. Because some spectacular plants are not cold hardy, we've also included a few tender perennials like purple fountain grass, or *Pennisetum setaceum*, in our research program.

The perennial group at MSU is led by Drs. Royal Heins, Art Cameron, and Will Carlson. More recently, Dr. Bridget Behe joined the group with a specific interest in marketing and garden performance. Dr. John Biernbaum has studied some nutritional requirements for perennial production. In the last seven years, 18 graduate students, five technicians and research associates, four post-doctoral scientists, two visiting scholars, and dozens of undergraduate students have made valuable contributions to the program.

Our primary goal is to understand the entire growth and developmental processes of herbaceous perennials from propagation to flower, not only to assist growers but also to impart new knowledge on plant growth and flowering responses. Our research program exists because of the strong financial support and exchange of ideas from a network of companies involved in all aspects of perennial production and sales. Their valuable contributions have been investments in their vision of successfully producing flowering herbaceous perennials.

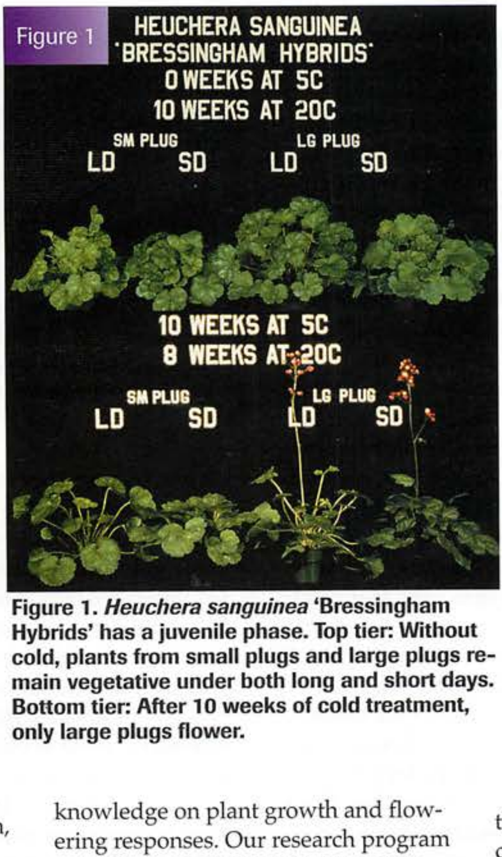


Figure 1. *Heuchera sanguinea* 'Bressingham Hybrids' has a juvenile phase. Top tier: Without cold, plants from small plugs and large plugs remain vegetative under both long and short days. Bottom tier: After 10 weeks of cold treatment, only large plugs flower.

Ripe For Research

We've selected perennials for this study based on several considerations, including species and cultivar popularity, suitability for container production, and industry recommendations. After initial trials, we studied promising plants more intensely to determine how environmental factors influence growth, development, and flowering.

As with any crop, producing high quality plants requires a combination of appropriate genetics, cultural procedures, and environmental conditions. The primary mechanisms that control flower initiation of herbaceous perennials are starting plant age (or size), vernalization (cold temperature treatments), and photoperiod (daylength). Once all other environmental requirements are met, time to flower is primarily a function of temperature. Finally, height control strategies are required to keep tall-growing plants in proportion to their container. With detailed, species-specific knowledge and successful implementation, growers can schedule the production of attractive, flowering herbaceous perennials in containers for one or more market windows (Figure 1).

Juvenility. Herbaceous perennials are propagated by virtually all available techniques: seed, stem and root cuttings, tissue culture, and division. Many species have a short juvenile phase, causing plants to perceive flowering signals early in their development. Some plants, especially those grown from seed, must reach a certain age or size before they can sense inductive conditions and subsequently flower.

One consistent method of estimating a plant's maturity is by counting its leaves or nodes. A plant's actual age doesn't offer enough information because it doesn't take into account the growing temperatures the plant encountered. For example, *Heuchera sanguinea* 'Bressingham Hybrids' has an extended juvenile period, and its actual age isn't an adequate measure of its readiness to flower. After a 10-week cold treatment only the larger plug-grown *Heuchera* seedling flowered, whereas the smaller plugs didn't flower (Figure 1). Small seedlings were produced in 128-cell plug trays and averaged seven leaves per plant, while large seedlings produced in 50-cell plug trays averaged 14 leaves per plant. Once a species' juvenility is quantified, you can grow plants to maturity and then expose them to inductive conditions for flowering.

Vernalization, Or Cold Treatment. Vernalization is a period of cold treatment that induces a plant to flower after being exposed to warmer temperatures. We've defined four general response categories that describe the effects of a cooling period on herbaceous perennials. For a few species, a cold period actually has detrimental effects on subsequent growth and flowering, and isn't recommended. For some, a cold treatment has no effect on flowering. The majority of herbaceous perennials either benefit from, or require, a cold treatment to flower. In these cases, plants not cooled may eventually flower, but flowering is generally poor, delayed, and nonuniform.

Vernalization length and effective temperature range varies by species. In general, optimum chilling temperatures for perennials are from 35°F to 44°F (2°C to 7°C). Many either benefit from or require six to 10 weeks of cold, but some species respond to as few as three weeks. Except for plants that have a juvenile period, it's easiest to provide plugs with cold temperatures before transplanting to the containers.

Photoperiod, Or Day Length. In temperate regions, the natural daylength, or photoperiod, changes dramatically during the year. Many plants have mechanisms that interpret seasonal changes by measuring daylength, and will then flower at a time of year that is favorable for pollination and seed dispersal.

Photoperiods that differ from natural ones can be created in the greenhouse, an already common practice with photoperiodic crops such as poinsettias and chrysanthemums. When natural photoperiods are short, an effective method of providing long days is to supply light for four hours during the middle of the night (for example, from 10 p.m. to 2 a.m.), known as night interruption (NI) lighting. You can use most lamp types to create long days as long as the light intensity is at least 10 footcandles.

Most northern herbaceous perennials can be grouped into three categories based on photoperiodic effects on flowering: 1) long days are not required; 2) long days are beneficial; and 3) long days are required. Plants benefiting from long days will eventually flower under short days, but will flower more quickly and uniformly under long days. Plants requiring long days simply will not flower when grown under short days. One such plant is *Rudbeckia fulgida* 'Goldsturm.' Regardless of cold treatment, 'Goldsturm' remains vegetative under daylengths of 12 hours or less, and blooms only when photoperiods are at least 13 hours or with a four-hour NI (Figure 2).

Temperature. The timing and scheduling of flowering herbaceous perennials varies among species, but we've made some generalizations. Plants grown at cooler temperatures take longer to flower, but may be more robust, have thicker stems, and have larger and greater numbers of flowers. With some exceptions, plants grown at constant warm temperatures (greater than 80°F (27°C)) have poor quality with few flowers. Forcing temperature's effect on flower size is readily apparent in *Campanula* 'Birch Hybrid' (Figure 3).

To flower several different types of herbaceous perennials at one time requires grower flexibility. You may need to use several temperature regimens with staggered planting dates to bring a range of perennials into flower on one predetermined date.

Figure 2. ***Rudbeckia fulgida*** **'Goldsturm' plants remain vegetative under photoperiods of 12 hours or less, and flower when photoperiods are at least 13 hours or with a four-hour night interruption (NI).**

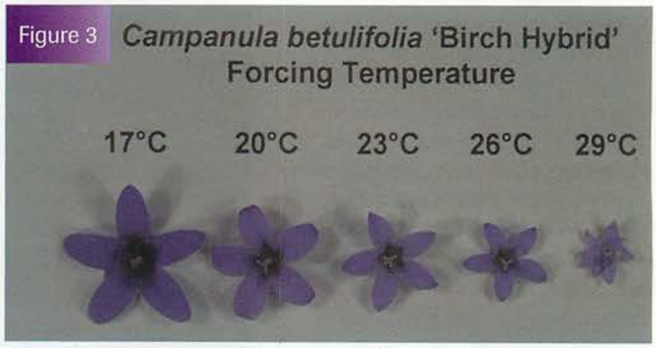


Figure 3. Flower size of ***Campanula*** **'Birch Hybrid' decreases as forcing temperature increases.**

Height Control. You may need to control height for potted flowering perennials. We've studied several techniques to control plant height, including photoperiod manipulation, spectral filters, temperature, nutrition and water stress, and growth retardants. Although growth retardants can be effective in slowing stem extension, these chemicals are considered by some as environmentally unfriendly, and some are not available in certain countries. Recently, we've started evaluating plastic spectral filters which selectively reduce transmission of far-red light, the waveband that promotes stem extension. This and similar filters show great promise for the future.

Present And Future

We have studied more than 200 cultivars and species to learn the best methods of producing flowering perennials and optimize growth and propagation. Thousands of plants are classified as herbaceous perennials, and the number of species we've studied is just a small portion. With all the species left untouched and more information needed on those we've already studied, our research program will certainly be active for years to come. **GG**

About the authors: Erik S. Runkle is a graduate research assistant and Drs. Bridget Behe, Art Cameron, Will Carlson, and Royal D. Heins are professors,Department of Horticulture, Michigan State University, East Lansing, MI 48824.

- Crop By Crop -

FORCING PERENNIALS 101

Editor's note: In this exclusive series, Michigan State University researchers tell growers how to give the public what they want: perennials in flower. Here we start with the basic science behind forcing techniques.

Table 1 Response of herbaceous perennials to long days (LD)

LD required (obligate LD plant)
Achillea filipendulina 'Cloth of Gold'
Asclepias tuberosa
Campanula carpatica 'Blue Clips'
Chrysanthemum coccineum 'James Kelway'
Coreopsis grandiflora 'Early Sunrise'
Coreopsis verticillata 'Moonbeam'
Gypsophila paniculata 'Double Snowflake'
Hibiscus x hybrida 'Disco Belle Mixed'
Lavandula angustifolia 'Hidcote Blue'
Oenothera missouriensis
Physostegia virginiana 'Alba'
Rudbeckia fulgida 'Goldsturm'

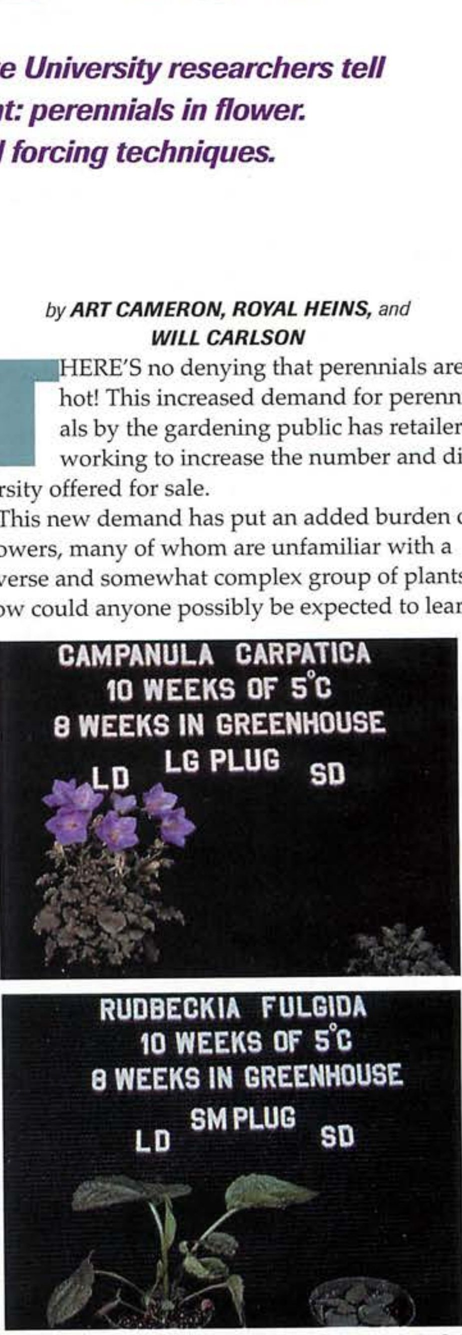
LD beneficial (quantitative LD plant)
LD horticulturally required
Coreopsis grandiflora 'Sunray'
Echinacea purpurea 'Bravado'
Gaillardia grandiflora 'Goblin'
Leucanthemum x superbum 'Snowlady' and other seedlings
Lobelia x speciosa 'Compliment Scarlet'
Salvia superba 'Blue Queen'
LD beneficial horticulturally
Astilbe arendsii (LD increase flower number)
Lavandula angustifolia 'Munstead Dwarf' (after cold, shorter plants under short days)
Platycodon grandiflorus 'Sentimental Blue' (LD slightly hasten flowering)

LD not required (day-neutral plants)
Aquilegia x hybrida (all cultivars)
Armeria x hybrida 'Dwarf Ornament Mix'
Armeria latifolia
Aster alpinus 'Goliath'
Delphinium elatum 'Blue Mirror'
Dianthus deltoides 'Zing Rose'
Heuchera sanguinea 'Bressingham Hybrids'
Iberis sempervirens 'Snowflake'
Leucanthemum x superbum 'Snowcap' (presumably a day-neutral clone)
Lewisia cotyledon
Linum perenne 'Sapphire'
Primula veris 'Pacific Giants'
Scabiosa caucasica 'Butterfly Blue'
Veronica longifolia 'Sunny Border Blue'
Veronica spicata 'Blue'

by **ART CAMERON, ROYAL HEINS,** and **WILL CARLSON**

THERE'S no denying that perennials are hot! This increased demand for perennials by the gardening public has retailers working to increase the number and diversity offered for sale.

This new demand has put an added burden on growers, many of whom are unfamiliar with a diverse and somewhat complex group of plants. How could anyone possibly be expected to learn



Dramatic effect of photoperiod: Plants labeled 'SD' were grown under 9-hour photoperiods. Plants labeled 'LD' were grown under 9-hour photoperiods with a 4-hour night interruption of 20 footcandles of light.

what's needed to bring every perennial to flower? Or, to make it even more difficult, how can a grower be expected to have them all in flower at a specified date and height.

Many popular herbaceous perennials have proved difficult to force for early sales but the exact reason was unknown. Again, the sheer number and diversity of perennials make the problem more difficult. But when taken individually, herbaceous perennials are no more complex to grow and bring to flower than growers' multitude of other crops.

Bringing a range of herbaceous perennials to flower on given dates to given specifications has been the objective of our research program in the Department of Horticulture at Michigan State University for the past 3 years. Only with a thorough understanding of flower induction mechanisms can we hope to bring plants to flower on specific dates.

Back To The Basics

Forcing perennial plants into bloom out of season is certainly nothing new. Based on past flowering research, we would expect photoperiod, vernalization, and juvenility to be the primary factors related to flower induction. Here's what we've learned about each.

Photoperiod

Because poinsettia and chrysanthemum are such important floricultural crops, the influence of short days (SD) on flower induction is well understood. Growers rarely have used long days (LD) to induce flowering. However, even during our first year's research, it was readily apparent that many herbaceous perennials species tested flowered in response to LD treatment. Horticultural researchers generally have divided plant response to LD into three major categories. It's convenient to subdivide one of the categories for application forcing.

❶ **LD required** (obligate LD plant). Plants in this group simply will not bloom under SD. In all cases, 4 hours of low-intensity, night-interruption lighting (10 footcandles) given from 10 p.m. to 2 a.m. can be used to induce flowering (Table 1).

❷ **LD beneficial** (quantitative LD plant). Traditionally, this category includes plants in which LD either increase the number of flowers or hasten the rate of flowering. We've subdivided this category into two parts:

❸ LD horticulturally required. These plants may bloom under SD, but the rate of flowering may be so slow or the number of flowers so greatly reduced that SD would not be very useful in practice (Table 1).

• **LD beneficial horticulturally.** For these plants, the beneficial effect of LD is marginal, even though it is real (Table 2).

• **LD not required** (day-neutral plants). These plants bloom under LD or SD (Table 1).

We have not yet investigated SD herbaceous perennials, but these include chrysanthemums, asters, and fall-blooming grasses such as *Miscanthus sinensis*.

Vernalization And Juvenility

Many, but not all, herbaceous perennials have a cold – or vernalization – requirement before they are capable of flowering. When grown from seed, plants of certain species also must reach a certain age or size before they are "mature" enough to perceive the cold treatment.

The age of a plant probably is estimated best by the number of leaves or nodes that it has developed before the beginning of a cold treatment. The age of the plant is not always adequate information because it does not take into account the temperature or photoperiod under which the plant was grown. There are three primary categories for the cold response of herbaceous perennials:

No cold required. Plants in this group can be forced directly to flower from 128- or 50-cell plugs. Smaller seedlings likely will take longer to force. Cold treatment of the plugs will not necessarily reduce subsequent forcing time (Table 2).

Cold will hasten or improve flowering. Plants in this group benefit from cold exposure. Juvenility is not a direct issue, although immature plants take longer to bloom regardless of when the cold treatment is delivered.

Cold required for flowering. Plants in this group must have a cold treatment or they will not flower. In all cases, seedlings must be mature before the beginning of the cold treatment. This will be the subject of our article next month.

We can't use this information right away, though, since we also must know the rate of flowering in response to starting material, temperature, plant growth retardants, etc. even when plants are grown under inductive conditions. But it's an important first step in developing forcing techniques for herbaceous perennials in general. **GG**

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Table 1

Herbaceous perennials. . .

. . . that do not require a cold treatment for flowering

From seed

Aquilegia x hybrida (Songbird series only)
Asclepias tuberosa (if not first exposed to SD)
Campanula carpatica 'Blue Clips'
Coreopsis grandiflora 'Early Sunrise'
Hibiscus x hybrida 'Disco Belle Mixed' (nondormant plants easily cold-injured)
Primula veris 'Pacific Giants'

From cuttings

Coreopsis verticillata 'Moonbeam'
Perovskia atriplicifolia

... whose flowering is hastened or improved by cold

From seed

Armeria x hybrida 'Dwarf Ornament Mix'
Armeria latifolia
Asclepias tuberosa (if dormant following exposure to SD)
Delphinium elatum 'Blue Mirror'
Dianthus deltoides 'Zing Rose'
Echinacea purpurea 'Bravado'
Gypsophila paniculata 'Double Snowflake'
Lobelia x speciosa 'Compliment Scarlet'
Oenothera missouriensis
Physostegia virginiana 'Alba'
Platycodon grandiflorus 'Sentimental Blue'
Rudbeckia fulgida 'Goldsturm' (immature plants flower much slower)
Veronica spicata 'Blue'

From cuttings

Scabiosa caucasica 'Butterfly Blue' (vegetatively propagated)

- Crop By Crop -

FORCING PERENNIALS 102

Here's a look at cold requirements of certain herbaceous perennials.

by **ART CAMERON, ROYAL HEINS,** and **WILL CARLSON**

HERBACEOUS perennials are an interesting and diverse group of plants whose sales have grown tremendously over the past decade. Retailers agree that flowering plants outsell nonflowering ones. Thus, our primary objective has been to understand environmental control of flower induction: particularly, to force plants to flower on specific dates and to precise specifications.

Flowering of seed-grown herbaceous perennials depends on seedling age or maturity, cold (vernalization), and photoperiod. Cold affects flowering of most seed-grown herbaceous perennials. We have found that even some vegetatively propagated species, such as 'Sunny Border Blue' veronica, require cold before flowering. We grouped herbaceous perennials into three categories based on their cold requirement for flowering:

1. Cold does not affect timing or flowering percentage.

2. Cold hastens or improves flowering.

3. Cold is required for flowering; plants will not flower from seed without cold.

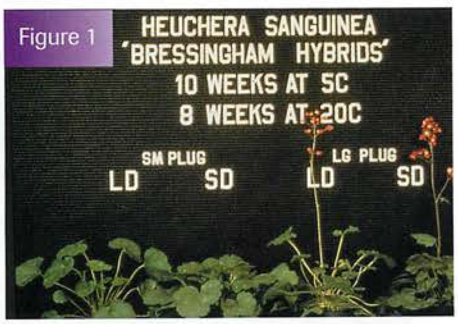
See our previous article for specific examples from the first two categories (March '96 GREENHOUSE GROWER, page 19).

Herbaceous Perennials That Require Cold To Flower

Certain herbaceous perennials will not flower unless they receive a cold treatment (obligate cold requirement). Usually, perennials with an obligate cold requirement must also attain some minimum age before the cold period begins. A plant's age can be estimated by leaf or node number.

'Bressingham Hybrid' coral bells (*Heuchera sanguinea*) is an example of a plant with an obligate cold and maturity requirement for flowering (Figure. 1).

Figure 1



'Bressingham Hybrid' coral bells (*Heuchera sanguinea*) is a perennial that will not flower unless it receives a cold treatment after reaching a minimum age.

Note that 'small' seedlings (from 128-cell trays) had about eight leaves; 'large' seedlings (from 50-cell trays), about 16.

In a subsequent experiment, 50% of seedlings with eight leaves flowered, while those with eight to 14 leaves before cold had an increasing flowering percentage. Only seedlings with 16 leaves or more consistently flowered 100% of the time. Thus, a given coral bell seedling may be mature when it has five to 16 leaves, but all members of the seedling population are not mature unless the leaf count is at least 16.

These requirements apply specifically to seed-propagated 'Bressing-ham Hybrid' and, presumably, specific seed sources. Other cultivars may have different juvenility or cold requirements. Since there is marked seedling variability in maturation rates, plant breeders should be able to develop lines that bloom and mature with fewer leaves.

Plants with an absolute cold requirement are listed in Table 1. We define, based on our research, the minimum age before cold for consistent flowering. These recommendations may not be valid for related species or closely related cultivars. When in doubt, we have erred on the side of leaf-count overestimation, since older seedlings should have improved flowering percentage.

Delivery Of The Cold Treatment

How cold? An excellent temperature for floral induction is 41°F (Easter lily, bleeding heart, and winter wheat), which also overcomes dormancy of many plants, including tulips and azaleas. Temperatures between 32°F and 45°F should work well. Temperatures just below freezing (≈28°F) can fulfill the chilling requirement for many species, even during bare-root storage.

Cold delivery. Seedlings in plug sheets can be cold-treated as is if they have the minimum leaf count. Otherwise, they can be transplanted and grown before cold treatment. Larger plants will more likely be mature and respond faster to treatments during forcing, but require more space during cooling.

We generally provide cold treatment in controlled-temperature facilities (41°F). Plants are given a small amount of light (≈25-50 footcandles), permitting photosynthesis during chilling. Under these conditions, most perennials exhibit little vegetative growth. However, *Scabiosa caucasia* 'Butterfly Blue' unfolded five leaves in 15 weeks at constant 41°F.

Growers who deliver cold treatments in hoop houses or other minimally heated structures need to ensure that root/crown temperatures do not fall below 28°F and that heat does not build up on warm, sunny days. We are not certain how chilling units are accumulated under high day/low night temperature variations. Regardless, inadequate temperature control could affect timing of the subsequent forcing profoundly. Temperature swings also create a large positive DIF (mathematical DIF-ference between day and night temperatures) that can excessively elongate some species.

How long? Ten weeks at 41°F is an effective cold period for most perennials that we have tested. Experiments on chilling duration often are confounded by increasing light levels and temperatures in spring. For instance, a plant cooled for 2 weeks and grown during winter when light levels and temperatures are lower will develop flowers more slowly than a plant chilled for 10 weeks and grown 2 months later in a warmer, brighter greenhouse.

In this case, the difference in developmental rate is not due solely to chilling. With similar lighting and temperatures, we found that *Campanula carpatica* flowers at the same time with or without cold treatment.

There also can be extensive seedling variation. For instance, Coreopsis 'Early Sunrise' was selected by plant breeders as a seedling that flowered under long days without a cold treatment from a species that otherwise requires cold. However, short days can sometimes substitute for some or all of the cold treatment.

Table 1. Herbaceous perennials that will not flower unless they first receive a cold treatment. Plants in this group must have reached a minimum age before the cold treatment begins. We recommend 10 weeks of cold (41°F) before forcing. After cold treatment, flower induction is completed under long days (LD) or natural days (ND). A 4-hour night interruption with 10 footcandles of light has proven effective for LD perennials.

Herbaceous Perennial	Minimum leaf numbers before beginning of cold treatment	Photoperiod for flower induction
Achillea filipendulina 'Cloth of Gold'	Unknown, but plants with 13 leaves at the beginning of the cold period did not flower.	LD
Aquiligia x hybrida – most cultivars	>15 leaves, although the number varies depending on species/cultivars.	ND
Aster alpinus 'Goliath'	>15 leaves; plants with fewer leaves will not flower.[1]	LD
Astilbe arendsii	Unknown, but few plants flowered with only 5-6 leaves.	LD
Chrysanthemum coccineum 'James Kelway'	>15 leaves to ensure flowering.	LD
Coreopsis grandiflora 'Sunray'	>16 leaves to ensure 100% flowering.	LD
Euphorbia epithymoides	Unknown, but seedlings with 17 leaves did not flower.	ND
Gaillardia grandiflora 'Goblin'	>12 leaves to ensure 100% flowering. Note that 50% of seedlings with 6 leaves flowered.	LD
Heuchera sanguinea 'Bressingham Hybrids'	>16 leaves to ensure 100% flowering. Note that 50% of seedlings with 6 leaves flowered.	ND
Iberis sempervirens 'Snowflake'	Probably >40 leaves. Trim plants after cold to increase branching. Blooms quickly.	ND
Lavandula angustifolia 'Munstead Dwarf'	>50 leaves to ensure flowering. Younger plants bloom inconsistently.	ND
Lewisia cotyledon	Unknown. Bloomed inconsistently from plugs.	ND
Linum perenne 'Sapphire'	Unknown, but immature plants (<70 leaves) flowered inconsistently.	ND
Salvia superba 'Blue Queen'	All plants with >10 leaves flowered.	LD
Veronica longifolia 'Sunny Border Blue'	Vegetatively propagated. No minimum size noted.	ND

It now appears that 'Early Sunrise' will only flower if given a period of short days during the seedling phase and prior to long days. 'Early Sunrise' seedlings germinated and grown entirely under long days did not flower.

In some cases, it is possible to avoid a cold treatment by growing seedlings (*Asclepias tuberosa* or *Hibiscus x hybrida*, for example) continuously under long days and avoiding the onset of dormancy induced by short days.

We anticipate several advances in the commercial application of cold treatments for flower induction of herbaceous perennials. **GG**

About the authors: Drs. Art Cameron, Royal Heins, and Will Carlson are professors, Depart-ment of Horticulture, Michigan State University, East Lansing, MI 48824.
They thank generous industry supporters and dedicated graduate students Beth Engle, Cathy Whitman, Cheryl Hamaker, Mei Yuan, Erik Runkle, and Paul Koreman – as well as Tom Wallace and Cara Wallace.

FORCING PERENNIALS

– Cold Requirements –

Cold can enhance many aspects of herbaceous perennial growth and development.

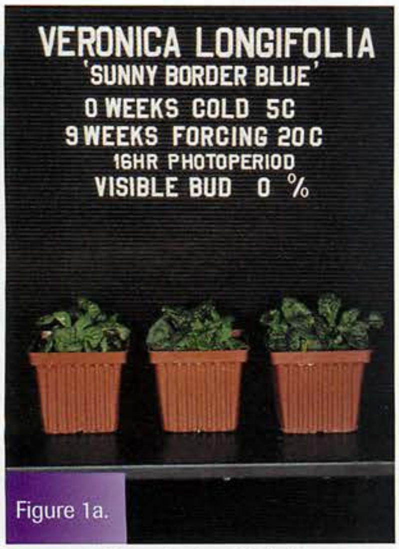


Figure 1a. ***Veronica longifolia*** **'Sunny Border Blue' grown without a cold treatment for 9 weeks in a 68°F (20°C) greenhouse under 16-hour day-extension lighting with high-pressure sodium lamps.** ***Photos courtesy of Leslie Finical.***

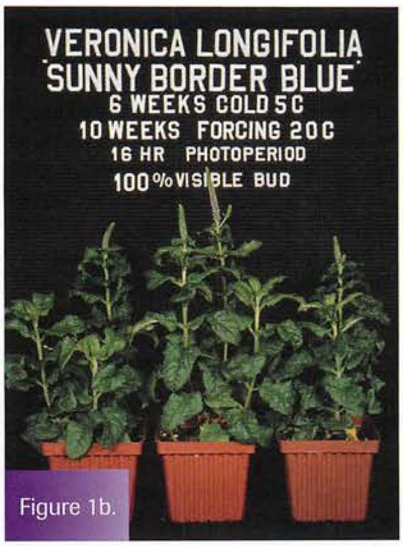


Figure 1b. All ***Veronica longifolia*** **'Sunny Border Blue' plants flowered after 6 weeks of cold treatment at 41°F (5°C) and 10 weeks of forcing at 68°F (20°C). When the experiment was repeated the following year, only 60% of the plants flowered after 6 weeks of cold.**

Figure 1c. ***Veronica longifolia*** **'Sunny Border Blue' after 15 weeks of cold treatment at 41°F (5°C) and 9 weeks of forcing at 68°F (20°C).**

by ***EMILY CLOUGH, LESLIE FINICAL, ARTHUR CAMERON, ROYAL D. HEINS,*** *and* ***WILL CARLSON***

HERBACEOUS perennials are plants with soft stems and are represented by a vast number of species, genera, and families. Not surprisingly, herbaceous perennials overwinter in diverse forms, depending on their relative hardiness and the severity of a particular winter.

As part of our research program on growth and development of herbaceous perennials, we are studying the effect of cold on plant performance. Exposure to cold temperatures can enhance many aspects of flowering, plant height, lateral branching, overall crop quality, and uniformity.

Many herbaceous plants have mechanisms to avoid growth and development during the unfriendly conditions of winter. Some become dormant and require exposure to cold, others require long days, and still others require both cold and long days before they initiate growth and move toward flowering.

In one experiment, *Veronica longifolia* 'Sunny Border Blue' remained vegetative until it was exposed to 6 weeks of cold. Then 60%-100% of the plants flowered in 80 days with an average of five inflorescences. After 15 weeks of cold, all plants flowered in about 63 days and had an average of 10 inflorescences. All plants were grown at 68°F (Figures 1a, 1b, and 1c).

A cold treatment also can broaden the span of effective photoperiods. Before cold treatment, plants of *Lavandula angustifolia* 'Munstead' flower only under long days. After a 15-week cold treatment at 41°F (5°C), 'Munstead' plants are day-neutral and can be forced to flower under any daylength.

What Constitutes Cold?

The range of cold temperatures that influences flowering is broad: usually 28°-45°F with an optimum of 41°F (5°C). Temperatures outside this range are generally not as effective. Temperatures lower than 28°F can be damaging to many perennials, especially to their root systems.

Delivering Cold Treatment

In our experiments, cold is delivered in environmentally controlled chambers set at 41°F (5°C). In the cooler, plants are provided with 9 hours of light (25-50 footcandles) from fluorescent bulbs which create a small amount of photosynthesis under short-day conditions.

But be aware of frost accumulation on the cooling chambers' coils. It reduces cooling efficiency and poses two problems: potential breakdown of coolers and loss of temperature control, resulting in nonuniform cold treatment. Appropriate defrost cycles are required.

In most Northern commercial nurseries, plants are given their cold treatments in minimally heated greenhouses. We recommend keeping greenhouses at a minimum of 28°F. Although crowns of many species can tolerate much lower temperatures, roots of many container-grown plants can be damaged below 28°F.

There are several challenges that growers face when cold is delivered in a greenhouse. Maintaining cool temperatures can be difficult on sunny days and is limited by the amount of venting. We have not studied whether frequent temperature shifts between cold nights and sunny, warm days might affect a plant's growth, development, or perception of cold during forcing.

Insufficiently cooled plants can be devernalized above 86°F (30°C). Exposure to such high temperatures can negate the beneficial aspects of cold. Cold treatments that are interspersed with periods of warm air temperatures may be less effective, so longer cold treatments may be necessary to compensate. But we have no definitive data.

Cooling in greenhouses may be a problem in warm Southern regions, so some Southern growers are using coolers with lights.

Figure 2. *Phlox paniculata* 'Eva Cullum' after 15 weeks of storage at 41°F (5°C). Plugs appear dead but close inspection reveals buds that will begin growing when transferred to forcing temperatures. *Photo courtesy of Erik Runkle.*

Cold Treatment Care

Before they are transfered to a cooler, plants are given a fungicide and insecticide drench to control disease and insect problems. During cooling, plants are watered about two times each week, as needed. When plugs are cooled, special attention is required so that they do not get over- or underwatered.

Generally, plants do not exhibit much growth during the cold treatment. A number of species, like *Phlox paniculata* 'Eva Cullum,' become dormant when kept at 41°F (5°C) and exhibit dieback of the leaves and stems (Figure 2). Those like astilbe maintain a healthy, green appearance (Figure 3).

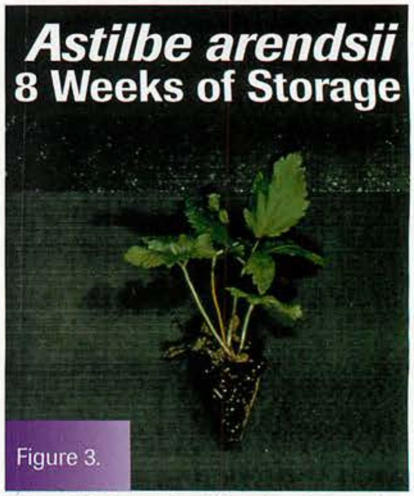


Figure 3. Plugs of astilbe after 15 weeks at 41°F (5°C). *Photo courtesy of Beth Engle.*

Some species grow noticeably. For example, *Scabiosa caucasia* 'Butterfly Blue' unfolded five leaves during a 15-week cold treatment. Temperatures lower than 41°F (5°C) are required to prevent development of such species.

Plant material. For perennials undergoing forcing, it is convenient to cool the seedlings while they are in plug trays, since they take the least amount of space. But hardy, mature plants can be cooled in containers of any size or even while bare-rooted.

It is important to ensure that any juvenility requirements are met before the treatment is given, or flowering will be inhibited or eliminated. For perennial plants, leaf or node number can be used as an estimate of age.

For instance, when *Heuchera sanguinea* 'Bressingham Hybrid' seedlings, with an average of eight leaves, were given a cold treatment, only 50% flowered. When seedlings were older before cold treatment, all of the crop flowered.

Allen Pyle of C. Raker and Sons, Inc., Litchfield, MI, suggests that chilling immature plants may be possible if the cold treatment is given in greenhouses where some growth occurs. We have not yet tested this suggestion, but it could offer an efficient way to fulfill two requirements with one step.

Duration of cold treatment. We have conducted experiments to test the effect of different lengths of cold treatment on flowering of herbaceous perennials. We divided plants into three main categories based on plant response to cold: cold required; cold beneficial; and no cold recommended. Plant growth and development can change with increasing lengths of

Table 1.

Aspects Of Growth And Development For Herbaceous Perennials That Respond To Cold Treatment

Species	Cold Category 1 = Cold Required 2 = Cold Beneficial	Recommendation (weeks of cold)	Increase % Flowering	Faster Flowering	Increase # Of Flowers	Increase Height	Comments
Anemone hupehensis	2	6-15	Yes	Yes	No	No	Improves uniformity
Campanula **'Birch Hybrid'**	1	6-9	Y	Y	Y	N	More than 12 weeks of cold makes plants sparse
Coreopsis grandiflora **'Sunray'**	1	10	Y	Y	Y	Y	Obligate cold requirement for this cultivar
Gaillardia x grandiflora **'Goblin'**	2	9-12	Y	Y	Y	N	Improves uniformity
Gaura lindheimeri **'Whirling Butterflies'**	2	6	N	N	Y	N	Improves vigor and sturdiness
Geranium dalmaticum	2	6-9	Y	Y	Y	N	With more than 9 weeks of cold, stems elongate excessively
Heuchera sanguinea **'Chatterbox'**	1	12	Y	N	Y	Y	100% flowering not reached until 12 weeks of cold
Monarda didyma **'Gardenview Scarlet'**	1	15	Y	Y	Y	Y	Height dramatically increases
Oenothera fruitcosa **'Youngii-Lapsley'**	1	3-15	Y	N	Y	N	Flower number increase seen only with 15 weeks of cold
Penstemon digitalis **'Husker Red'**	2	9-15	Y	Y	Y	Y	Height dramatically increases
Phlox paniculata **'Eva Cullum'**	2	9	N	N	Y	N	Number of flowers increases with 15 weeks of cold
Physostegia virginiana **'Alba' and 'Rosea'**	1 'Alba' 2 'Rosea'	12-15	Y	Y	Y	Y 'Alba' N 'Rosea'	Poor performance without cold
Rudbeckia fulgida **'Goldsturm'**	2	6	Y	Y	Y	Y	Increase in flower number not seen until 9 weeks of cold
Salvia nemorosa **'May Night'**	2	6-9	N	N	Y	N	Improves uniformity; height decreases with cold
Salvia xsuperba **'Blue Queen'**	2	6-9	N	Y	Y	N	Improves uniformity; height decreases with cold
Saxifraga arendsii **'Triumph'**	1	9-15	Y	Y	N	N	Bulk before cold to increase flower numbers
Stokesia laevis **'Klaus Jelitto'**	2	6-9	Y	Y	N	N	Improves uniformity
Veronica longifolia **'Sunny Border Blue'**	1	12-15	Y	Y	Y	N	Branching promoted after 12 weeks of cold

Table 2.

No Cold For These Herbaceous Perennial Plants

Species	Comments
Asclepias tuberosa (if kept under long days)	Blooms fine from seedling when grown continuously under long days; can be difficult to hold in plug tray during cold treatment. Very sensitive to overwatering. A pinch at transplanting increases branching.
Campanula carpatica 'Blue Clips'	Cold treatment not required, but can slightly hasten flowering (10 days). Can be stored at low temperatures.
Coreopsis grandiflora 'Early Sunrise'	This cultivar of coreopsis has no cold requirement, while most other coreopsis cultivars will not flower without a cold treatment.
Echinacea purpurea 'Bravado'	Cold treatment not required, but can slightly hasten flowering by 1-2 weeks. Can be stored at low temperatures.
Gypsophila paniculata 'Happy Festival'	No effect of cold on plants grown in high light conditions; cold treatment can be beneficial if plants are grown in low light. We had problems with Anthracnose during the cold period.
Hibiscus moscheutos 'Disco Belle Mixed'	Hibiscus plugs are very difficult to keep at low temperatures; best just to grow under continuous long days.

cold. We have attempted to identify an optimum length of cold for perennials that respond to cold treatments (Table 1).

Cold required and cold beneficial. For most species in these categories, increasing the cold treatment shortens the time to flower while increasing flowering percentage and uniformity. For example, 60% of *Physostegia virginiana* 'Rosea,' a cold-requiring species, flowered after 3 weeks of cold in an average of 105 days.

After 6 weeks of cold, 100% of Rosea flowered, requiring only 89 days (Figure 4). For *Geranium dalmaticum*, a cold-beneficial species, 80% of the plants started from 72-cell plugs flowered without a cold treatment in 80 days. After 3 weeks of cold, all plants flowered in 63 days.

Longer cold durations generally increase the number of flowers per plant. With 3 weeks of cold, *Campanula* 'Birch Hybrid' had an average of 40 flower buds when the first flower opened. After 6 weeks of cold, they had about 110 flower buds per plant (Figure 5a). More than 200 flower buds were produced when the duration of cold was increased to 9 weeks (Figure 5b).

Some species increase in height following increasing cold durations. The increase can be quite dramatic. For example, *Penstemon digitalis* 'Husker Red' attained a height at first flower of 24, 28, or 32 inches (60, 70, or 80 centimeters) following 9, 12, or 15 weeks of cold, respectively. But cold treatments do not affect height for many perennials and even reduced height of *Salvia nemorosa* 'May Night.'

No cold recommended. A few species do not require cold to improve flowering but usually can be stored at low temperatures (Table 2). For two species, we recommend avoiding cold treatment. *Hibiscus moscheutos* 'Disco Belle Mixed' are damaged between 32° and 41°F and are also very sensitive to over- or underwatering during cooling.

Asclepias are also difficult to store at low temperatures because of extreme sensitivity to overwatering. Both species can be flowered directly from seed if kept under long days without exposure to cold.

Formula For Success: Cold Treatment

1. Use environmentally controlled chambers set at 41°F (5°C) or greenhouses kept between 28°F (-2°C) and 45°F (7.5°C).

2. Provide 9 hours of light using fluorescent bulbs (25-50 footcandles) in chambers.

3. Make sure juvenility requirements are met before cooling plants.

4. Water plants as needed but avoid too much or too little water during cooling.

5. Choose a length of cold appropriate for each species.

6. Plants can be transferred directly from cold to 68°F without any problems, although plants can be devernalized at temperatures of about 86°F.

Future Directions

We look forward to increased efficiency in production because of crop scheduling based on optimum conditions for flower induction, including plant juvenility, cold duration, and photoperiod. Manipulating flowering requirements could allow year-round production and open up new markets for consumers with different needs and desires. **GG**

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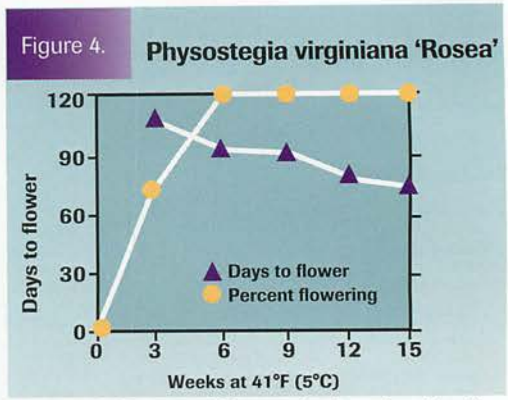

Figure 4. Influence of increasing lengths of cold on flower timing and flowering percentage of *Physostegia virginiana* 'Rosea.' The indicated cold treatments were given in a cooler at 41°F (5°C). Plants were grown in a 68°F (20°C) greenhouse under 16-hour day-extension lighting with high-pressure sodium lamps.

Figure 5a. Influence of increasing cold durations on number of flower buds of *Campanula* 'Birch Hybrid.' Plants were given 0-, 3-, and 6-week cold treatments at 41°F (5°C) and grown in a 68°F (20°C) greenhouse under 16-hour day-extension lighting and high-pressure sodium lamps. *Photo courtesy of Leslie Finical.*

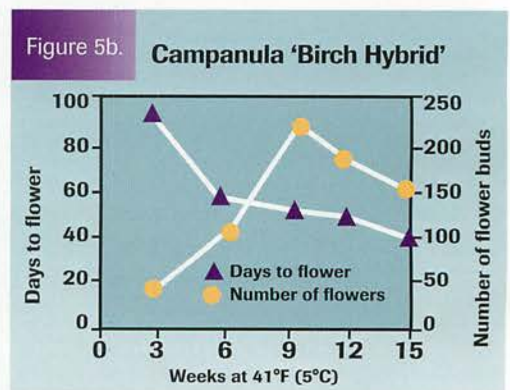

Figure 5b. Influence of increasing cold durations on flower timing and number of flowers for *Campanula* 'Birch Hybrid.'

FORCING PERENNIALS

– Root Zone Management –

Learn the growing conditions to avoid or embrace.

by *JOHN BIERNBAUM* and *MARY-SLADE MORRISON*

PROVIDING optimum environmental conditions is difficult when many species are being grown in one area. Fortunately, when it comes to water, media, fertilizer, or pH, rarely do we need to provide for the best growth. Growers simply need to know which conditions provide acceptable growth and which conditions to avoid. Usually, plants tolerate a wide range of root zone conditions and only a few must be avoided.

Michigan State University's (MSU) perennial forcing research team has successfully grown a wide range of crops in one area at one time. All species were grown under one general root zone management program – one fertilizer solution applied to one root medium to maintain a desired pH and electrical conductivity (EC).

Last year, we evaluated root zone conditions outside the standard range and observed plant response. From October 1- June 1, 18 herbaceous perennials were forced in a 20°C greenhouse under 16-hour days with HPS supplemental lighting and no growth regulators. All crops were grown in 5-inch square pots containing root media formulated at MSU.

Since flower initiation is regulated by temperature or photoperiod, differences because of water or nutrient management were not expected. There were statistical differences in days to flower and flower number, but no species varied in days to flower by more than 5-7 days. Actually, more flowers developed under high moisture conditions, not high fertilizer rates.

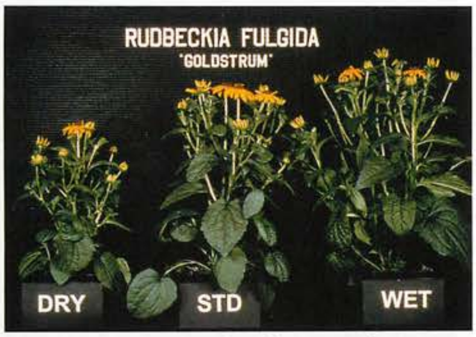

Figure 1. As moisture level increased, *Rudbeckia fulgida* 'Goldsturm' obtained greater plant mass in a $5^1/_2$-inch container.

Figure 2. *Echinacea purpurea* 'Magnus' plant height increased when container moisture level was kept above 75% container capacity at a constant liquid fertilizer rate of 125-12-125 ppm NPK.

Water Availability

We used three watering levels: standard, dry, and wet. Using the standard treatment, we added 8 fluid ounces when 50% of container capacity was lost. For the dry treatment, we maintained the medium at less than 60% of container capacity. And for the wet treatment, the medium was kept at greater than 75% of container capacity, but not saturated, by adding 4 fluid ounces of water when the pot, medium, and plant reached a predetermined weight.

Like bedding plants, responsiveness to water varied among herbaceous perennial species (see Table 1). Several species increased in plant size with each increase in water. Some species increased in plant size with only wet conditions, and a few species decreased in size when kept dry. The wet treatment increased plant size but not the height of several species (Figure 1) because of larger leaves or lateral branching. For echinacea only (Figure 2), the wet treatment increased internode length and final height.

In a second set of treatments, we compared the standard root medium (70% peat/30% perlite) with a 100% peat medium and a medium comprised of 50% composted bark, 30% peat, and 20% perlite. There were no differences among plants grown in the three root media.

By managing water to prevent saturation or excess drying, herbaceous perennials can be grown in a wide range of component blends. Using a larger container size is helpful because it provides adequate drainage and aeration. Plants that are grown outside or in potentially saturating conditions would benefit from a porous root medium.

Fertilizer Concentration

We applied three levels of macronutrient fertilizer to evaluate plant response. The standard nutrient solution contained 125 ppm nitrogen (N), 12.5 phosphorus (P), 125 potassium (K), 133 calcium (Ca), 30 magnesium (Mg), 25-30 sulfur (S), and micronutrients. We altered nutrient availability by changing the concentration of N, P, and K while keeping a constant level of micronutrients or by eliminating the water soluble P from the base nutrient solution.

At the experiment's start, N and K concentrations were 62, 125, or 250 ppm with P at 6, 12.5, or 25 ppm, respectively. Because there was no difference in soluble salt levels between the low and medium treatments, we reduced the low treatment to 31-3-31 ppm NPK 5 weeks into the study. Irrigation was from the top of the pot, and we kept water collection trays under each pot to prevent leaching.

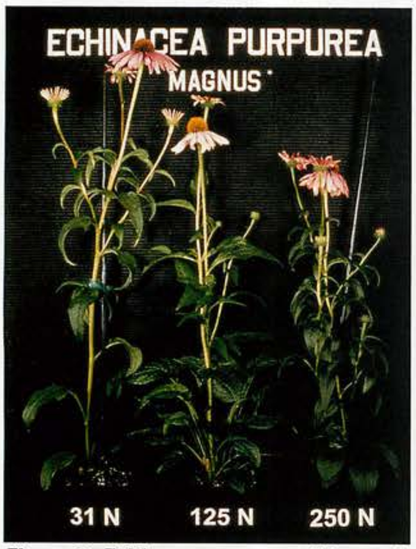

Figure 3. ***Echinacea purpurea*** **'Magnus' height increased as constant liquid fertilizer rate decreased from 125 ppm N to 31 ppm N.**

Table 1. **Root Zone Management: Key Concerns For Herbaceous Perennials**

Species	*Observations and Key Concerns*
Astilbe chinesis	Leaf area, plant size increased with high moisture. Chlorosis with basic nutrient solution (NS) and high medium pH. Avoid low H_2O.
Campanula carpatica 'White Clips'	Tolerates all conditions. Branching, buds increase with 250 ppm.
Coreopsis grandiflora 'Sunray'	Plant size increases with more water. Taller plants grown at highest H_2O.
Coreopsis verticillata 'Moonbeam'	Plant size increases and taller plants grown at highest H_2O. Chlorotic leaves with pH > 7.0. Sensitive to acidic drench. Low K.
Delphinium grandiflorum	Challenging plant, weak roots. Moisture, pH extremes.
'Blue Mirror'	Avoid rushed production.
Echinacea purpurea 'Magnus'	Leaf area, plant size increase at highest H_2O. Height, root increase at low fertilizer. High H_2O increases plant height by internode stretch.
Gaillardia x *grandiflora* 'Goblin'	Plant size increases with increasing H_2O without changing height. Low rate of constant liquid fertilizer (CLF) may decrease plant size.
Hemerocallis 'Stella de Oro'	Low H_2O increases days to flower and decreases plant height, size. Plant size decreases with basic NS. Sensitive to low H_2O. Basic NS leading to high pH. Leaf tissue elements are low.
Heuchera sanguinea 'Firefly '	Leaf area, plant size increase at highest H_2O, peat medium, and lowest fertilizer. Avoid excessive fertilization.
Hibiscus moscheutos 'Disco Belle Hybrids'	Plant size, height increase with increasing H_2O. High CLF rate decreases plant height. Avoid low Ca, low pH leading to Fe and Mn in tissue. Avoid low temperatures and HPS lighting.
Hosta 'Undulata Variegata'	Plant size increases at highest H_2O. Root mass increases at low CLF. Avoid excessive fertilization. Leaf tissue elements are low.
Lavandula angustifolia 'Munstead'	Leaf area, plant size increase at highest H_2O, while plant height unaffected. Shorter plant grown under low H_2O.Sensitive to high pH, excessive fertilization. Watch roots.
Leucanthemum x *superbum* 'Snow Cap'	Plant size increases with more water. High K. Low rate of CLF may decrease plant size.
Perovskia atriplicifolia	Plant size increases with more water, height differences at extremes. Possible longer time to flower under dry conditions.
Rudbeckia fulgida 'Goldsturm'	Leaf area, plant size increase with more water. Shorter plant with less water. Avoid pH and fertilizer extremes. Fe, Mn accumulation at pH < 5.5.
Salvia x *superba* 'Blue Queen'	Tolerated all conditions, except smaller plant with less water. Low amounts of water decrease plant size.
Scabiosa caucasica 'Butterfly Blue'	Tolerated all conditions. Plant size increased with more water.
Sedum 'Autumn Joy'	Tolerated all conditions except smaller plants with less water. Leaf tissue elements out of average range.

The low rate of constant liquid fertilizer combined with preplant fertilizer and no leaching produced acceptable plants for most species. Some differences at the low fertilizer rate were decreased overall plant size, increased plant height (Figure 3), or increased overall plant size.

In a few cases, increased fertilizer rate (250 ppm N and K) decreased plant height or height and overall plant size. In most cases, using high fertilizer rates did not affect growth enough to justify the increased risk of high soluble salts or fertilizer runoff.

The root system's size and the balance between shoot and root growth has a significant impact on the quality and performance of container-grown plants. Lower fertilization rates favor the development of a strong root system. This was particularly evident for hosta (Figure 4), hemerocallis, and echinacea.

Contrary to some recommendations, high P rates did not stimulate root growth. The balance of root to shoot growth is more sensitive to changes in N than to P levels. We tried to establish P deficiency symptoms by using a zero P nutrient solution, but all species showed adequate levels.

Root Medium pH

We altered root medium pH in three ways: by drenching the medium with sulfuric acid; by using a basic drench of K bicarbonate within 2 weeks of planting; or by slowly applying a high nitrate fertilizer with high alkalinity water or a high ammonium fertilizer with a low alkalinity water. The rapid pH change using sulfuric acid or K bicarbonate was phytotoxic to some species.

Most species tolerated a wide range of media pH, but some were sensitive to low pH, high pH, or both (Figure 5). It was not our intent to define a pH optimum, only to indicate whether high or low pH can result in problems (see Table 1).

Although the herbaceous perennials tested tolerated a wide pH range, our recommended strategy is to maintain a pH of 5.8-6.5. Below 5.8, some species accumulate excessive iron (Fe) or manganese (Mn), which can alter nutrient balance. At this level, P is more soluble and prone to leaching, and nitrification is inhibited.

At pH levels greater than 6.5, trace element deficiency and low P are concerns. We detected high levels of Fe and Mn in rudbeckia, lavandula, and hibiscus in leaf tissue samples in the standard and acidic treatments.

The acidic nutrient solution had low Ca and Mg, while the basic nutrient solution had high levels. We did not observe any detrimental effects from either low or high levels of Ca and Mg. Since we adjusted pH with hydrated lime, there was minimal residual lime. The less lime in the media and the longer the crop time, the greater the probability of low Ca and Mg levels.

Figure 4. Hosta 'Undulata Variegata' increased root mass with decreased constant liquid fertilizer rate (31-3-31 ppm, 125-12-125 ppm, 250-26-250 ppm NPK).

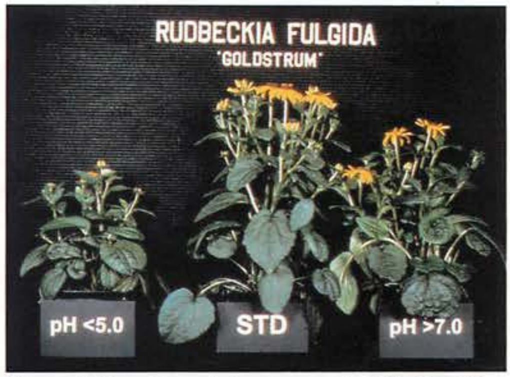

Figure 5. Growth and development of *Rudbeckia fulgida* 'Goldsturm' were stunted at pH extremes.

Figure 6. *Rudbeckia hirta* 'Goldsturm' exhibited purplish tissue dominating on the underside of older leaves, which showed an accummulation of Fe and Mn in tissue analysis at low pH.

Formula For Success: Root Zone Management

1 Establish a correct pH (5.8-6.5) and use a properly limed root medium. Balance the irrigation water alkalinity, nitrogen form, and acids to provide a neutral reaction nutrient solution. Select nitrogen form on the desired reaction - acidic or basic - and not on the type of growth desired.

2 Herbaceous perennials can be grown with low rates of fertilization. A constant, minimal leaching application of 125-12-125-100-30-30 ppm N-P-K-Ca-Mg-S with micronutrients is a good place to start.

The fertilization goals are to account for the water nutrient content when preparing the nutrient solution. Maintain the root medium EC at 0.5-1.5 (SME) or 0.3-0.75 (1:2), and consider soil tests and plant appearance. Lowering macronutrients, not micronutrients, will require some adjustments in formulating water-soluble fertilizers.

3 Media moisture level controlled by irrigation method and timing will have the biggest impact on plant size and quality if media pH and nutrient levels are properly maintained. Develop watering recommendations for each crop based on the desired plant size.

4 Flower initiation is tightly regulated by temperature or photoperiod, not water or nutrient management, so follow recommendations for proper temperature and photoperiod.

5 Leaf tissue analysis can be a useful prevention and problem-solving tool. Ask for help from an experienced professional to interpret results. Keep organized records of any tissue analysis samples.

Leaf Nutrient Analysis

When nutrient problems arise, the most reliable analytical tool is often leaf nutrient analysis. For many plants, we can compare leaf nutrient levels to a common standard acceptable range and determine if a particular nutrient is deficient or toxic. For herbaceous perennials forced in the greenhouse in soilless mixes, few standard values exist.

We collected leaf samples and analyzed six of the 12 treatments. Mature leaves were gathered from the middle of the plant at flowering. Usually, leaf samples are collected before flowering, but this was not feasible since we had to collect flowering and plant size data from the same plants.

The N content for all species under the standard treatment only ranged from 5.2%-5.6%, and the values were similar at low, standard, and high N fertilization rates. The K levels of leaf tissue ranged from 1.8%-7.3%, but for most species was within the expected range of 2%-5% (see Table 2).

The range of Ca, Mg, Fe, and Mn values were large among species. Fe levels are usually twice as high as Mn levels in plant tissue, but in four species, Mn was two or more times Fe levels with no detrimental effect. Foliar symptoms associated with nutrient problems were chlorosis in hibiscus and distortion in rudbeckia. The root of these problems was not clearly determined, but leaf samples contained higher than average Ca and Fe levels.

With rudbeckia, we think there is a strong probability of Fe or Mn toxicity at low to medium pH, levels similar to geraniums. Symptoms include a darkening of the underside of older leaves followed by tissue death (Figure 6). Since rudbeckia is the perennial plant of the year for 1999, many growers will be producing this crop. Plan to keep medium pH up like you would with geraniums.

Eight species had abnormally high Mg levels. Sampling technique, old leaf age, or MSU's water, which is high in Mg, could be the culprits. Zinc (Zn) levels in seven crops were higher than the normally accepted upper range. Hosta and hemerocallis, two plant species which account for a large percentage of all perennials sold, tended to have lower than average leaf K, Ca, Mg, Fe, Mn, and Zn levels. **GG**

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Table 2. **Leaf Tissue Analysis from Root Zone Management Experiment**

Interpretation Ranges	N %	P %	K %	Ca %	Mg %	S %	Na ppm	Fe ppm	Mn ppm	Zn ppm	B ppm	Cu ppm	Mo ppm
Minimum Critical	2.0#	0.2	2.0	0.5	0.3	0.1	@	50	30	20	25	5	0.25
Desired Lower Range	3.0	0.4	3.0	0.6	0.4	0.2	100	75	50	25	30	10	0.50
Desired Upper Range	5.0	0.8	5.0	2.0	0.8	0.4	3000	300	300	75	80	20	5.00
Maximum Critical	6.0?	2.0?	6.0*	4.0**	2.0**	***	6000?	500	500	200?	200?	50?	15?
Campanula carpatica	5.4	0.7	5.0	1.6	1.1	0.2	142	200	98	190	68	3	0.26
Coreopsis grandiflora	5.4	0.4	3.5	2.1	1.4	0.2	185	262	160	101	63	4	0.12
Coreopsis verticillata	5.4	0.4	1.8	1.2	0.6	0.2	87	102	198	59	73	3	0.12
Delphinium grandiflorum	5.4	0.8	6.0	1.6	1.1	0.2	182	88	69	100	22	8	0.12
Echinacea purpurea	5.6	0.7	4.6	1.6	1.5	0.2	234	84	138	43	136	4	0.24
Gaillardia x grandiflora	5.2	0.5	6.0	2.1	0.9	0.2	466	67	77	60	45	5	0.43
Hemerocallis	5.3	0.3	3.0	0.6	0.3	0.2	111	72	97	21	55	2	0.12
Heuchera sanguinea	5.5	0.4	2.1	1.1	0.6	0.2	258	57	78	45	32	7	0.12
Hibiscus moscheutos	5.4	0.4	2.4	3.2	1.7	0.2	291	885	202	147	56	3	0.12
Hosta	5.4	0.3	4.2	1.0	0.7	0.2	530	53	96	20	24	4	0.12
Lavandula angustifolia	5.3	0.4	3.9	2.0	1.2	0.2	216	1130	446	96	39	3	0.12
Leucanthemum x superbum	5.2	0.9	7.3	1.5	1.1	0.2	106	64	160	133	26	4	0.12
Perovskia atriplicifolia	5.5	0.5	5.3	0.9	0.4	0.2	123	99	87	50	51	6	0.12
Rudbeckia fulgida	5.3	0.3	3.3	3.3	1.3	0.2	132	1078	198	108	66	4	0.12
Salvia x superba	5.4	0.8	4.4	1.7	0.9	0.2	149	100	200	50	48	5	0.47
Scabiosa caucasica	5.3	0.5	5.2	0.9	0.4	0.2	216	155	108	35	47	6	0.16
Sedum	5.4	0.9	4.3	4.4	1.1	0.2	230	81	227	133	76	8	0.12
Difference to Consider	0.3	0.1	0.5	0.3	0.1	0.0	115	150	37	20	8	1	0.15

Minimum Critical: Values below the minimum usually indicate a need for additional fertilizer and a possible growth limiting situation.
# indicates critical values will likely vary depending on the plant type. Some landscape plants survive with low N concentration.
@ Na, sodium is not an essential plant nutrient and is not required for normal plant growth.

Maximum Critical: Values above the critical usually indicate overfertilization. Toxicities and possible reduction in growth would be possible for Na, Fe, Mn, Zn, and B.
? indicates that maximum critical values are not firmly established.
*K can accumulate to as much as 10% without detrimental effects other then inducing deficiencies of other elements such as Ca and Mg.
**Ca and Mg are not expected to be toxic, but can lead to induced deficiencies of other elements, particularly Fe and Mn if Mg is excessive.
***S has not been shown to accumulate to toxic levels.

FORCING PERENNIALS

– Perennial Height Control –

Follow these strategies to regulate perennial plant height.

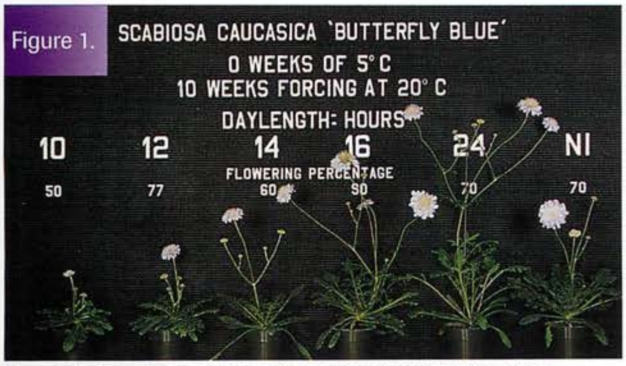


Figure 1. In some species, stem elongation increases as photoperiod increases. For example, scabiosa height increased as the photoperiod increased from 10 to 24 hours. Photoperiods consisted of a 9-hour natural day extended with incandescent lamps. NI represents a 4-hour night interruption.

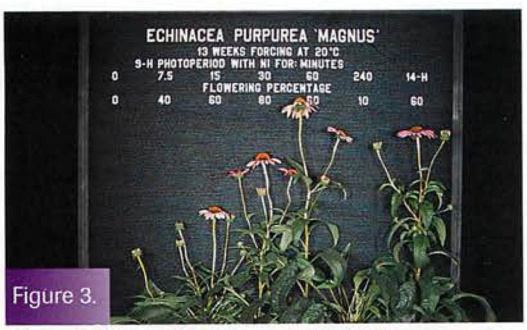


Figure 3. Flowering echinacea's height can be suppressed with short durations of night interruption (NI) during short days. NI treatments were provided during the middle of 15-hour dark periods with incandescent lamps. Plants given 15 minutes of NI were less than half the height of those given ≥1 hour of NI, but flowering was delayed by 1-2 weeks.

by ***ROYAL D. HEINS, ERIK S. RUNKLE, ARTHUR CAMERON, and WILL CARLSON***

WHEN you are producing flowering herbaceous perennials, you might find that the plants are taller than what you expected. Some perennials are naturally tall, but others become too tall because of environmental or cultural factors.

Since consumers are more attracted to flowering plants than green, vegetative ones, controlling height is essential.

This requires understanding factors that contribute to stem extension. By using various strategies, growers can successfully produce perennials to meet desired height specifications.

GENETICS

Within a species, genetic variation exists so that some perennial cultivars grow significantly taller than others. For example, *Gaillardia* x*grandiflora* (Blanket flower) 'Burgundy' and 'Goblin' grow much taller than 'Baby Cole.'

Selecting naturally short-growing cultivars reduces or eliminates the need for height control. But many tall-growing species have no short cultivars, and demand for these plants still exists.

Therefore, other strategies must be used to produce short plants.

CONTROLLING PHOTOPERIOD

Many herbaceous perennials require long days for flower induction. Light duration for flowering varies from 12 hours for some species to almost 16 hours for others. Under natural short daylengths, electrical lighting can deliver photoperiods that are substantially longer than what is required for flowering.

In some species, stem elongation and plant height increases as photoperiod increases (Figure 1).

Limiting the photoperiod required for flower induction will help limit stem elongation.

Controlling daylength is easier in early spring when natural days are short because growers can limit the electrical lighting duration. Black cloth can be used during long summer days, but many growers do not have such a system. Adversely, temperature can become too high under black cloth in the summer.

Limited induction photoperiod can reduce elongation during bolting. When black cloth is available during long summer days or when plants are forced in the natural short days of spring, placing perennials under short days after they have been induced to flower can control the height of some species, such as *Coreopsis xgrandiflora* or tickseed.

Bob Lyons at Virginia Polytechnic Institute called this technique limited induction photoperiod (LIP). Using LIP, plants are exposed to long days for a period sufficient for flower induction – generally 2-3 weeks. Then plants are shifted back to short photoperiods – 9 or 10 hours of light. Flowers continue developing to open bloom, but stem elongation is greatly retarded.

Problems with LIP include delayed flowering and fewer flowers. Also, LIP is not effective in all species (e.g., *Asclepias tuberosa)* because flowers will cease to develop or even abscise under short days. Although 2-3 weeks of lighting using LIP is adequate to induce flowering in many species, we suggest using long days until the first flower buds are visible.

Plants should then be returned to natural photoperiods in winter months or placed under shortened daylengths using black cloth when photoperiods are naturally long (after mid-March).

Short night breaks can reduce echinacea's height. Controlling echinacea height can be difficult. One method we discovered is to provide short night-break lighting treatments to plants growing under short days. Lighting for only 15-20 minutes at a low intensity (10 footcandles) in the middle of the night is adequate to induce flowering under short days, but plants are only half the height of those grown with the traditional 4-hour night break (Figure 3). Flowering can be delayed 1-2 weeks, compared to plants under longer durations of night break. Unfortunately, most long-day perennial species will not flower with such short night interruptions, so this technique may have limited usefulness.

INCANDESCENT LIGHTS PROMOTE STRETCH

Electrical lighting can simulate natural long days effectively under natural short days. Incandescent lamps are most commonly used to create long days because they are inexpensive and easy to install. Unfortunately, incandescent lamps are rich in far-red light, the part of the spectrum that promotes stem elongation.

Plants provided with long days by incandescent lamps will often be taller than those lit by other lamps, such as cool-white fluorescent, metal halide, or high-pressure sodium (Figure 4).

We suggest using high-pressure sodium lamps for photoperiod control. Although these lamps are expensive to install, electrical costs will be lower and plants will be shorter than those lit with incandescent lamps.

WATER STRESS HAS LIMITED POTENTIAL

Using water stress for height control is common in bedding plant production, especially during the dark, early spring season when plants dry slowly. Small quantities of water can be applied to keep plants alive, but they will still be stressed.

Water stress will limit stem elongation in perennials. But height control using water is more problematic.

Controlled application of water to pots is more difficult than with flats. When many perennials are grown in late

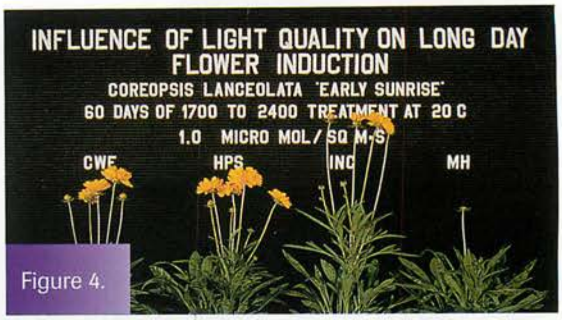


Figure 4. Incandescent (INC) lamps are rich in far-red light and can promote stem elongation in a variety of species, including coreopsis. Cool-white fluorescent (CWF), high-pressure sodium (HPS), or metal halide (MH) lamps can be used effectively to extend natural daylengths with less stem extension. *Photo courtesy of Cathy Whitman.*

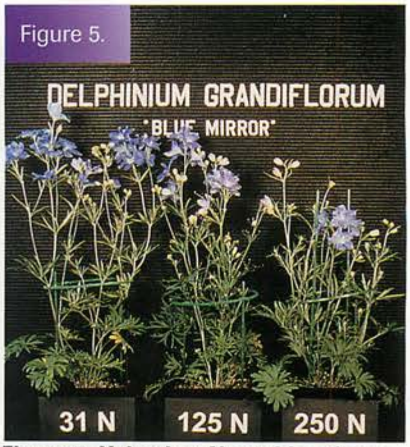


Figure 5. Using low N nutrition does not reduce plant height in many herbaceous perennials. The opposite occurs. Delphinium plant height decreased as the rate of constant liquid fertilizer increased from 31 to 250 ppm N. *Photo courtesy of Mary-Slade Morrison.*

spring and summer, the time between limited irrigations must be short. If water is not applied when it is absolutely required, severe foliar damage and even death can occur.

While water can be a powerful tool for regulating height, there certainly is a high risk associated with it during bright, dry, warm weather.

NUTRITION

Limiting nutrients, typically nitrogen and phosphorous, has been used to control plant height.

Low nitrogen does not reduce height. Low nitrogen nutrition often has been used to control bedding plant size and height. We have not observed any height control response on herbaceous perennials fertilized continually with nitrogen rates from 62 to 250 ppm. In fact, quite the opposite occurs. Plants fertilized at the lowest concentration (62 ppm) were either the same height or taller than plants fertilized at higher concentrations (Figure 5).

If anything, low nitrogen nutrition resulted in thin growth of some plant species, creating unattractive plants compared to those provided with more nitrogen. These results suggest that limiting nitrogen fertilization will not control plant height for many herbaceous perennials.

Figure 6. Phosphorus levels in a fertilization program have little, if any, effect on herbaceous perennial height if the soil has a preplant P charge. In echinacea, plants were similar heights when they were grown using a nutrient solution deficient in P (left) or with moderate P concentrations (right). ***Photo courtesy of Mary-Slade Morrison.***

Ammonium-to-nitrate ratio does not affect plant height. Most growers say increasing ammonium concentrations will increase plant height significantly. But supporting evidence is sparse and for perennials, it is nonexistent. Plants of 15 different species were grown with ammonium-nitrogen percentages ranging from 5% to 50%, and there were no differences in plant height.

Phosphorus levels have little effect. One of the deficiency symptoms of phosphorus is stunting. Plug and bedding plant growers have traditionally used low phosphorus to help control height.

In our trials, herbaceous perennials were transplanted into soil containing a typical preplanting phosphorus charge. The presence or absence of phosphorus in the nutrient solution did not influence plant height (Figure 6).

AVOID PLANT ELONGATION

Plant spacing. Herbaceous perennials' ecological survival strategy when confronted with competition from other plants is to elongate. Plants spaced closely elongate, putting them in more competitive positions to harvest light.

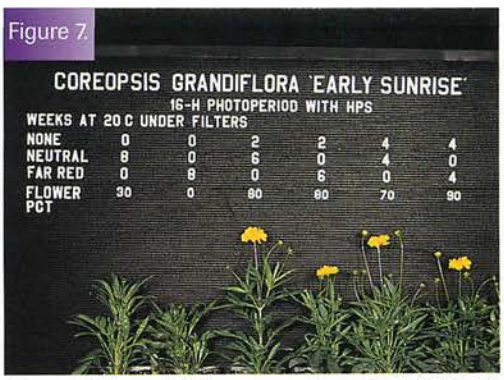


Figure 7. Far-red filters can reduce the height of some plants, including coreopsis. Plants were grown under high light with a 16-hour photoperiod for 0, 2, or 4 weeks, then were transferred to either a neutral or far-red filter with a 16-hour photoperiod until flowering. Percentage flowering indicates the proportion of plants in flower after 8 weeks in the greenhouse.

When sun-loving plants are not crowded, but widely spaced, they will elongate slowly and branch out widely to maximize light interception. Therefore, one of the most powerful growth retardants for herbaceous perennials is wide spacing. Although spacing is not consistent with maximum productivity, it's still a powerful height-control strategy.

Far-red filters can reduce plant height. Plants perceive competition based on the ratio of red and far-red light. When plants are widely spaced, leaves and stems are exposed to equal amounts of red and far-red light.

When they get closer, they are exposed to more far-red than red light. This far-red light promotes stem elongation. If far-red light is removed from sunlight, then the red to far-red ratio will not change dramatically by increasing spacing, and stem elongation will not be promoted.

We have found that one experimental filter, developed by the University of Reading

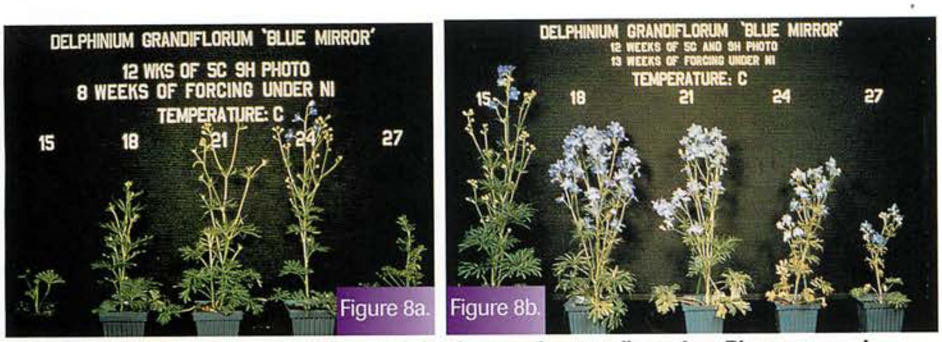


Figure 8. Low temperatures do not result in shorter plants at flowering. Plants grown in warmer temperatures may initially be taller because of faster development. (a) Delphinium plants grew faster and were taller after 8 weeks of forcing. (b) But plant height at flower was greater at lower forcing temperatures. ***Photos courtesy of Shi-Ying Wang.***

and British Visqueen, effectively reduced some species' plant height (Figure 7). Far-red filters are being developed by several companies worldwide.

TEMPERATURE

A common perception among many growers is that warmer greenhouse temperatures will make perennials grow taller. This statement is only partially true. Warmer temperatures will hasten plant development, including plant height (Figure 8a).

Final plant height at flower is not increased by forcing at warmer temperatures. We have grown dozens of perennial species at temperatures from the mid-50s to the mid-80s, from the start of forcing to flowering. In every case, plants grown at warm temperatures were either the same height or shorter at flower than those grown at cool temperatures (Figure 8b).

Warm temperatures should never be equated with causing tall plants, just like using cool temperatures is not a long-term method of height control.

DIF can reduce elongation. Many flowering potted and bedding plants respond to DIF, the relationship between day and night temperature. Stem elongation increases as day temperatures progressively become warmer than night temperatures.

Campanula carpatica has responded to DIF similar to many other species. DIF should control stem elongation on many herbaceous perennial species.

Cool nights and warm days (positive DIF) will result in tall plants. Plants grown under equal day and night temperatures (zero DIF) or cooler days than nights (negative DIF) will be shorter.

GROWTH RETARDANTS REDUCE ELONGATION

For many herbaceous perennial species, using growth retardants is the only way to maintain plant height at an acceptable level.

We have evaluated A-Rest, B-Nine, Bonzi, Cycocel, and Sumagic on more than 40 species. No one growth retardant controls height on all species.

The two chemicals that show the most widespread efficacy are B-Nine and Sumagic. Cycocel had the smallest range of height control.

For several growers, Sumagic at 10-15 ppm has been the most effective and widely used growth retardant. A second or third application often is required as the plant grows. The concentration and number of applications should be based on grower observations and decisions.

In addition, timing the application of growth regulators with the period of maximum plant elongation will be key to suppressing plant height. We have tested Florel on a number of plant species, and further information on its efficacy will soon be published. **GG**

About the authors: Drs. Royal D. Heins, Arthur C. Cameron, and Will Carlson are professors, and Erik S. Runkle is a graduate research assistant, Department of Horticulture, Michigan State University, East Lansing, MI 48824. Information in this article originated with several current or previous graduate students and research associates in MSU's herbaceous perennial program, including: Mary-Slade Morrison; Cheryl Hamaker; Alison Frane; Paul Koreman; Shi-Ying Wang; and Cathy Whitman.

FORCING PERENNIALS

Greenhouse temperatures affect the timing and quality of herbaceous perennials.

by ***GENHUA NIU, ALISON FRANE, ROYAL D. HEINS, ARTHUR CAMERON,*** *and* ***WILL CARLSON***

Figure 1.

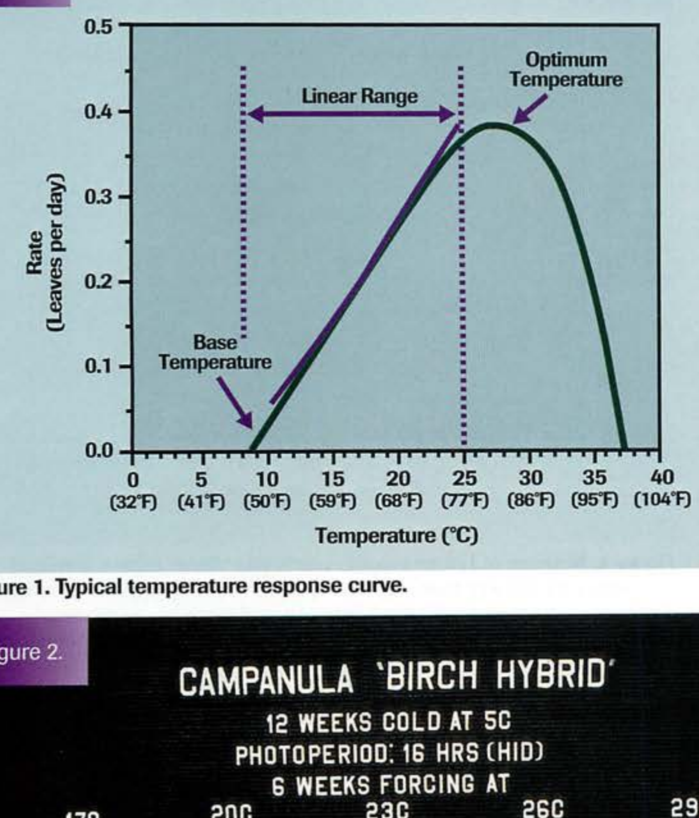


Figure 1. Typical temperature response curve.

Figure 2.

Figure 2. *Campanula* 'Birch Hybrid' plants flower most rapidly from 68°F to 79°F (20°C to 26°C). *Photo courtesy of Alison Frane.*

TEMPERATURE is one of the critical environmental factors that influence herbaceous perennials. Plant growth, development rate, and quality, including leaf morphology and flower size and number, are affected by temperature.

Development Rate

The rate that leaves and flowers develop depends primarily on temperature, or more specifically, plant temperature. Plant growth typically follows a similar pattern in response to temperature (Figure 1). Below the base temperature, there is no growth. As temperature increases, growth rate increases until the optimum temperature is reached, at which time growth rate is at a maximum. Above the optimum temperature, growth rate decreases.

For many perennial species, the development rate increases linearly when the temperature is between the base and optimum temperatures. Plants become increasingly stressed as temperatures increase above the optimum temperature. It's useful to know the optimum temperature if one wants to grow plants as quickly as possible without stress.

Base and optimum temperatures vary within and between species and are related to climatic origin. For example, *Campanula* 'Birch Hybrid' plants flowered at 68°, 73°, and 79°F (20°, 23°, and 26°C) after 6 weeks of forcing, but only 10% had flowered at 63° or 84°F (17° or 29°C) (Figure 2).

FORCING PERENNIALS

Time to flower decreased as temperature increased from 63°F to 75°F (17°C to 24°C), then it increased as the temperature increased from 75°F to 84°F (24°C to 29°C) (Figure 3). Growing *Campanula* 'Birch Hybrid' above 75°F (24°C) doesn't hasten flower development, but does delay flowering. Thus the optimum temperature for most rapid production of this variety is about 75°F.

Plant development is a function of the 24-hour average daily temperature, if day and night temperatures are always within the linear range. Day and night temperatures are equally effective at promoting development rate. For example, the leaf unfolding rate for Easter lily 'Nellie White' increased linearly as the average daily temperature increased from 57°F to 86°F (14°C to 30°C), regardless of how the temperature was delivered (Figure 4).

In another example, *Campanula carpatica* 'Blue Clips' was grown under nine different combinations of day and night temperatures, which were created by moving the plants twice a day among three greenhouse sections set at 59°, 68°, and 77°F (15°, 20°, and 25°C), respectively. The difference between the actual day and night temperatures ranged from –15°F to 22°F (-10°C to 12°C). Time to flower decreased as the average daily temperature increased from 59°F to 77°F, but was not influenced by how the temperature was delivered during the day and night.

When plants are exposed to day or night temperatures outside the linear range (below the base temperature or above the optimum temperature), development is slower than when they are grown at the same day and night temperatures. This is true even though the average daily temperature is same. Therefore, if a crop is behind schedule, you can hasten its development by growing the plants at a constant 24-hour temperature at or near the optimum temperature for the developmental rate.

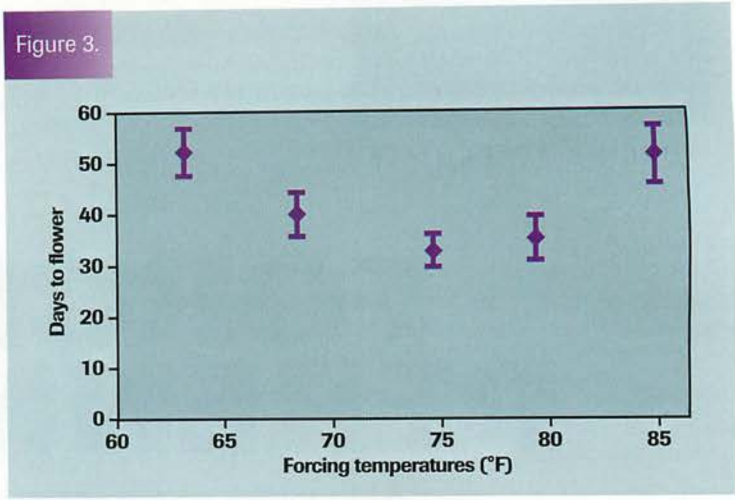


Figure 3. Time to flower in *Campanula* 'Birch Hybrid' decreases as the forcing temperature increases from 63°F to 73°F and it increases as forcing temperature increases from 73°F to 84°F. The optimum temperature is around 75°F for this species.

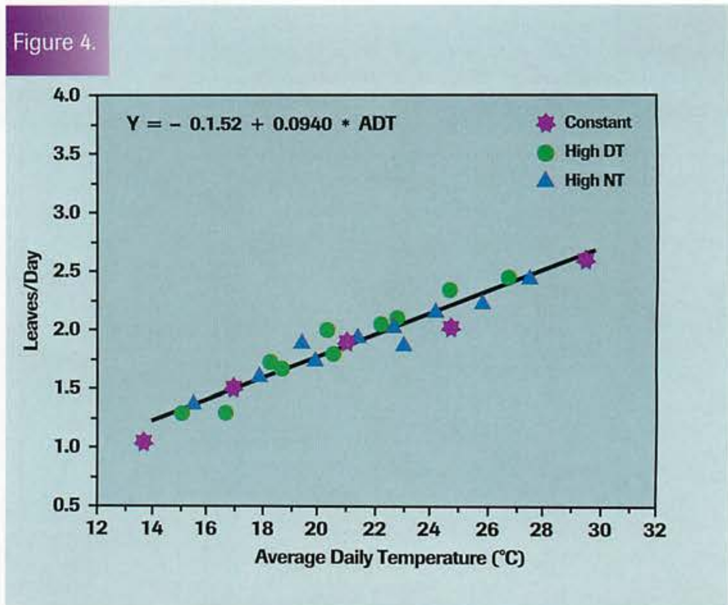


Figure 4. Number of *Lilium longiflorum* 'Nellie White' leaves unfolded per day with a higher day than night temperature, with a higher night than day temperature, and with the same day and night temperatures. Source: Karlsson et al., 1988. Quantifying temperature-controlled leaf unfolding rates in 'Nellie White' Easter lily. J. Amer. Soc. Hort. Sci. 113(1): 70-74.

Flower Size

The flower size of herbaceous perennials generally decreases as the forcing temperature increases. In some cases, the effect can be quite dramatic. The flower diameters of *Campanula* 'Birch Hybrid' and *Coreopsis verticillata* 'Moonbeam' decreased significantly as temperature increased from 63°F to 84°F (17°C to 29°C) (Figures 5 and 6).

High temperatures also can cause flower abnormalities. Some flowers on *Campanula* 'Birch Hybrid' developed abnormalities, such as doublings, at 84°F (29°C).

A temperature transfer experiment with *Campanula carpatica* 'Blue Clips' and *Campanula* 'Birch Hybrid' showed flowers were most sensitive to temperature after the first visible bud (Figures 7 and 8). Plants of both species were initially grown at a constant 68°F (20°C) and then were transferred at visible bud to 57°, 63°, 68°, 73°, or 79°F (14°, 17°, 20°, 23°, or 26°C) until flowering. Other plants were grown at a constant 57° or 79° F (14° or 26°C).

For 'Blue Clips,' the flower diameter on plants grown at a constant 57°F was similar to plants initially grown at 68°F until visible bud and then transferred to 57°F until flowering. The flower diameter on plants grown at constant 79°F was similar to plants grown at 68°F until visible bud, and then transferred to 79°F until flowering.

For 'Birch Hybrid,' the flower diameter on plants grown at a constant 57°F was similar to plants grown at 68°F until visible bud and then transferred to 57°F until flowering. But the

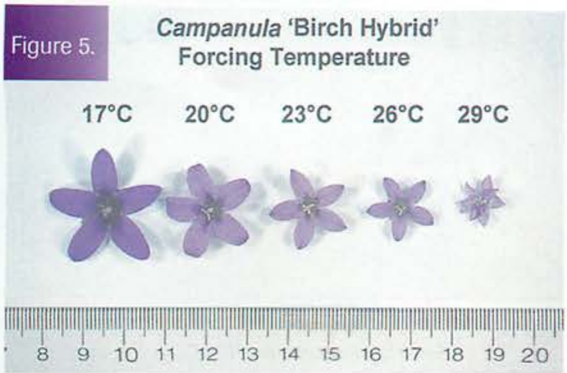


Figure 5. Flower size of *Campanula* 'Birch Hybrid' is largest at 63°F (17°C) and decreases as temperature increases from 63°F to 84°F (17°C to 29°C). *Photo courtesy of Alison Frane.*

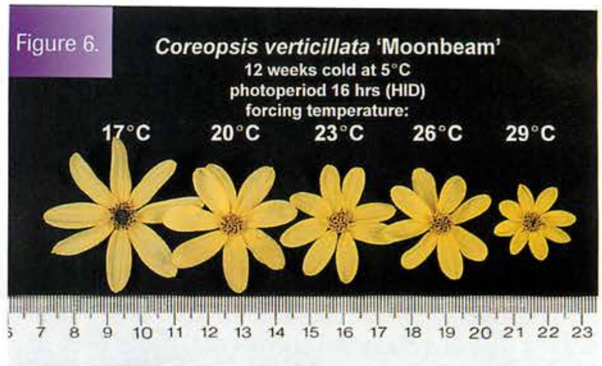


Figure 6. Flower size of *Coreopsis verticillata* 'Moonbeam' is largest at 63°F (17°C) and decreases as temperature increases from 63°F to 84°F (17°C to 29°C). *Photo courtesy of Alison Frane.*

flower diameter on plants grown at a constant 79°F was smaller than those grown at 68°F until visible bud and then transferred to 79°F until flowering. This is most likely because 79°F is out of the linear range (Figure 3).

Thus, within the linear range, the temperature before visible bud has little effect on flower size. In addition, the temperature above the optimum before visible bud may reduce flower size.

Number Of Flower Buds

Increasing the forcing temperature not only reduces flower size but also the number of flower buds. In *Rudbeckia fulgida* 'Goldsturm' and *Coreopsis grandiflora* 'Sunray,' the number of flower buds decreased 75% and 80%, respectively, as temperature increased from 60°F to 79°F (16°C to 26°C) (Figure 9). Often, the measured number of flowers is a consequence of enhanced lateral branching when plants are grown at cooler temperatures.

Plant Height

For many bedding and potted plants, stem length and plant height increase as the difference between day and night temperatures (DIF) increases. Herbaceous perennial plants have similar responses to DIF. For example, the plant height of *Campanula carpatica* 'Blue Clips' increased linearly as the DIF increased from –15°F to 22°F (Figure 10).

In addition to DIF, plant height is influenced by average daily temperature. Increasing temperature hastens plant development and increases growth. But the increased temperature doesn't increase final plant height at flower. Quite the opposite, plant height at flower is often higher when they are forced at lower temperatures (Figure 11).

Leaf Morphology And Characteristics

The diversity in shape, texture, and coloration in leaves makes hostas attractive and admired plants in the garden. Temperature has a dramatic influence on morphology and coloration of hosta leaves. For instance, increasing the forcing temperature changes the ratio of leaf length to leaf width (Figure 12). Leaves are wider and shorter, with

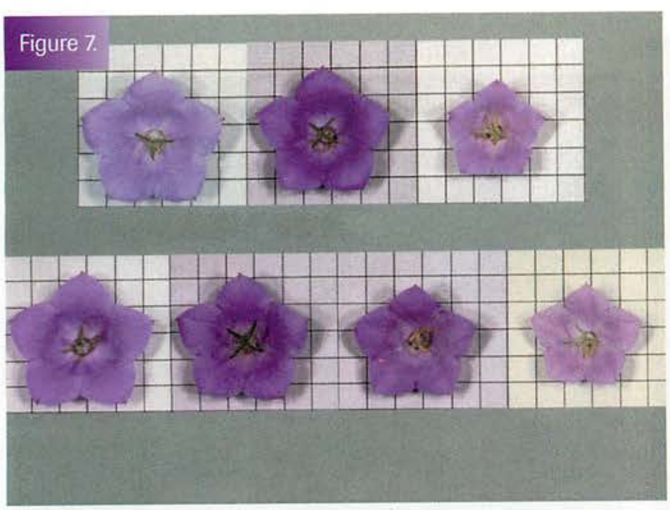


Figure 7. Effect of temperature transfer on flower size of *Campanula carpatica* 'Blue Clips.' Plants were grown initially at 68°F and then transferred at visible bud (VB) to 57°, 63°, 73°, or 79°F. Other plants were grown at a constant 57° or 79°F.

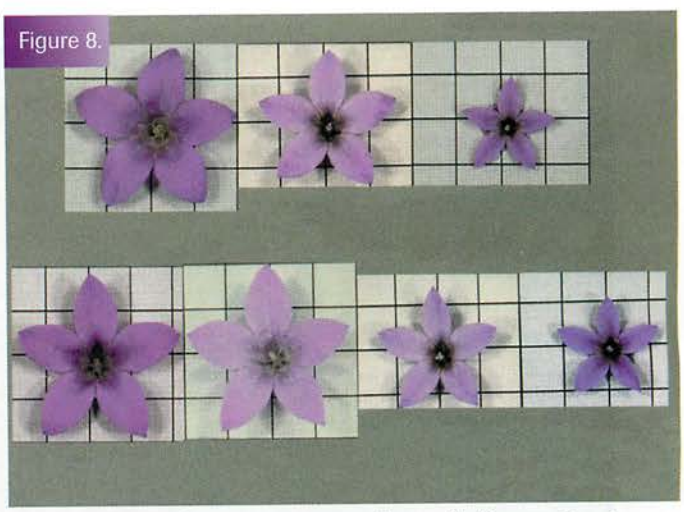


Figure 8. Effect of temperature transfer on the flower size of *Campanula* 'Birch Hybrid.' Plants were grown initially at 68°F and were then transferred at visible bud (VB) to 57°, 68°, or 79°F. Other plants were grown at a constant 57° or 79°F.

better coloration at cooler temperatures. A similar phenomenon has been observed on a number of hosta cultivars.

Keys To Remember

Temperature not only influences the finishing time of a plant, but also influences the final appearance of the plant. Understanding the temperature response of a particular species is the key to avoid growing that plant under stressful temperatures. To schedule a crop while maintaining high quality, knowing the other temperature effects on plant quality, such as flower size, flower bud number, and plant height, is necessary.

It is interesting to speculate how garden performance of perennials is influenced by temperature. The British have a well-deserved reputation for growing quality perennials in their outdoor gardens. At least some of this success is likely a result of the cooler growing temperatures during the summer months, which promote tall plants with better branching and more, larger flowers. **GG**

About the authors: Genhua Niu is a visiting research associate, Alison Frane is a graduate research assistant, and Drs. Royal D. Heins, Arthur Cameron, and Will Carlson are professors, Department of Horticulture, Michigan State University, East Lansing, MI 48824.

Figure 9.

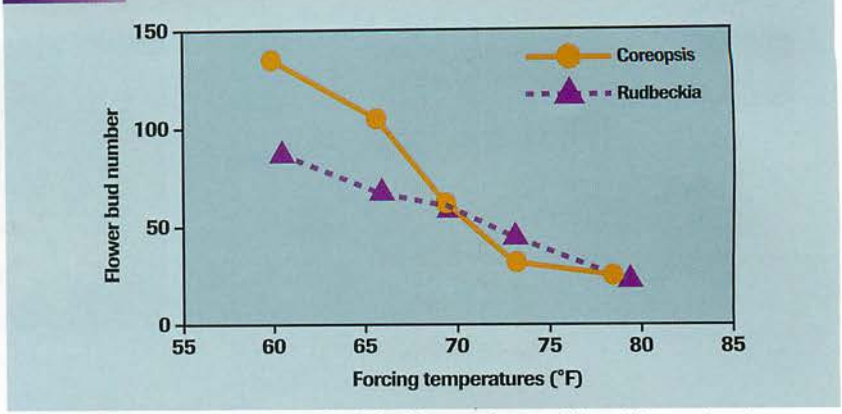


Figure 9. The number of flower buds in *Coreopsis grandiflora* 'Sunray' and *Rudbeckia fulgida* 'Goldsturm' decreases as the forcing temperature increases from 60°F to 79°F (16°C to 26°C). Source: Yuan et al., 1998. Effect of forcing temperature on time to flower of *Coreopsis grandiflora, Gaillardia xgrandiflora, Leucanthemum xsuperbum,* and *Rudbeckia fulgida.* HortScience 33(4): 663-667.

Figure 10.

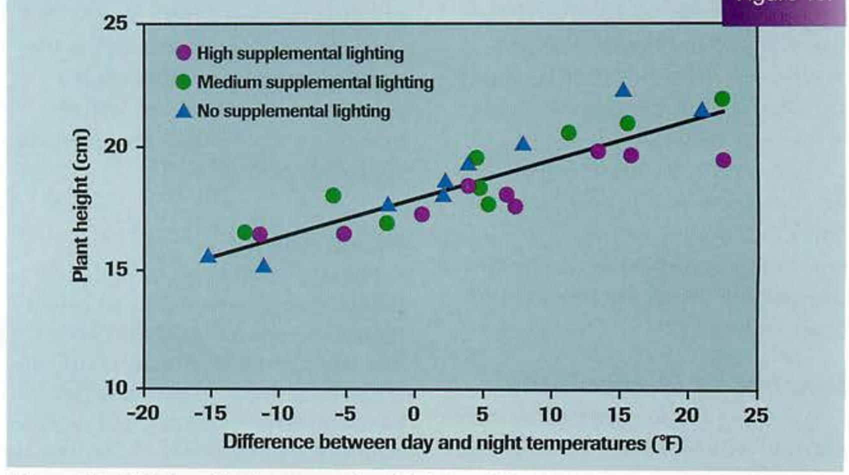


Figure 10. Relationship between plant height of *Campanula carpatica* 'Blue Clips' and the difference between day and night temperature. Plants were grown at three light conditions: without supplemental lighting or with supplemental lighting at 145 or 250 µmol $m^{-2} s^{-1}$ provided by a high-pressure sodium lamp for 12 hours per day.

Figure 11.

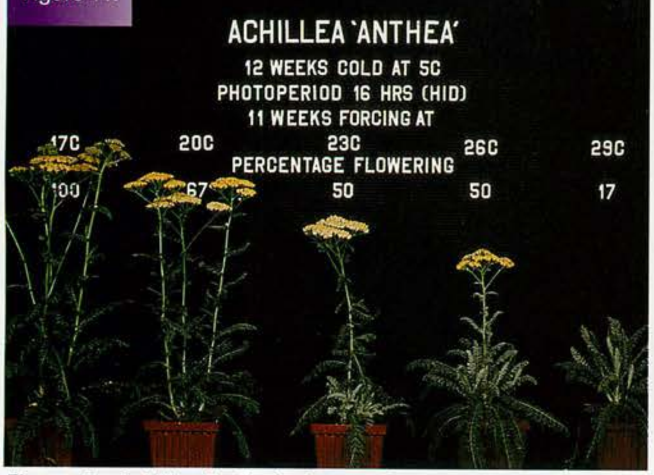


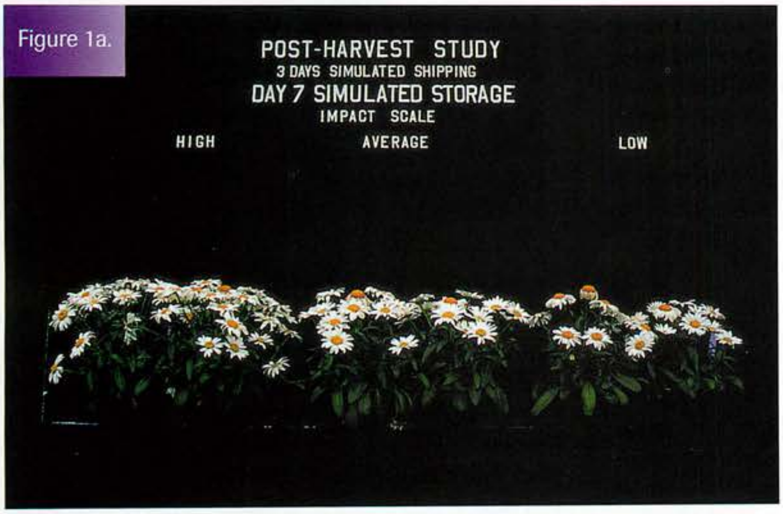
Figure 11. *Achillea* 'Anthea' plants at flower are taller when forced at low forcing temperatures compared to high forcing temperatures. *Photo courtesy of Alison Frane.*

Figure 12.

Figure 12. Lower forcing temperature makes the leaves wider and shorter and gives better coloration in *Hosta* 'Undulata.' *Photo courtesy of Beth Fausey.*

FORCING PERENNIALS

Marketing forced perennials can be a challenge for some growers.



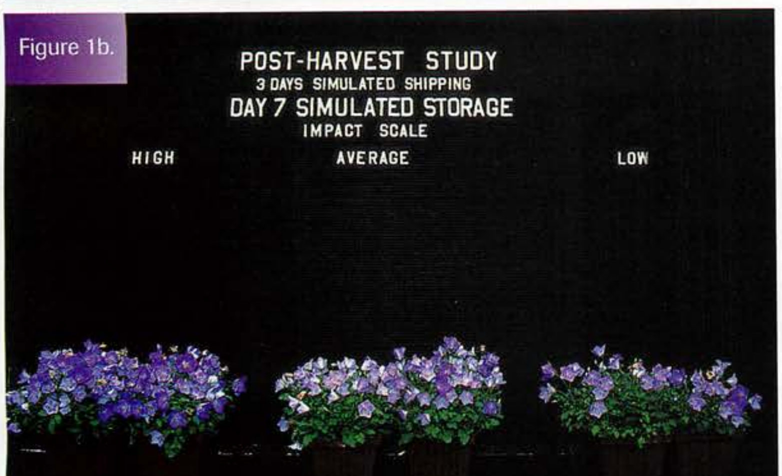


Figure 1. Perennial researchers are identifying potential plants that perform well inside the home for a short time and then can be planted outdoors. At Michigan State University, researchers placed forced plants of *Leucanthemum* 'Snow Caps' (a) and *Campanula* 'Blue Clips' (b) in a simulated shipping environment for 3 days and then in a simulated retail display for an additional 7 days. Some species performed better than others, but the experiment provided preliminary results for plants that should receive further testing.

by ***BRIDGET K. BEHE***

PERENNIAL sales are growing by leaps and bounds in some markets. People want to add the beauty of these repeat bloomers to their homes and gardens. Whether perennials are a new product line for your business or an old favorite, these tips may help you market perennials more effectively to some consumer groups.

1. Market Segmentation

One of the fundamental components of a marketing strategy is market segmentation. Market segmentation attempts to identify all potential customers of a product or service and group them into definable categories. This process allows marketers to select particular groups or segments and concentrate marketing efforts on those groups. Such marketing efforts could include tailoring marketing strategies to focus on an individual segment or developing products and services that specifically address a particular segment's needs.

One of the more useful ways to segment a market or group of consumers is to divide them up by how much of a product they use, how much they know about a product or hobby, or how much they enjoy it.

You may recall the 80/20 rule, which states that 80% of your profits come from the sale of 20% of your products. It's true for buying because 80% of your sales come from 20% of your customers. We sometimes call the 20% the "heavy half." These people are the heart of every business. They enjoy your products more, spend more money on them, and just buy them more often. Understanding this group can bring insight into purchases that could eventually be made by other consumers.

Some consumers buy perennials because they are focused on the plants themselves. Like us horticulture professionals, they find joy in having something new or novel. While touting a new perennial to plant fanatics is effective, they likely make up a small portion of all your customers.

Learn from them what plants do well in their gardens. By asking questions, you can understand the problems or challenges other customers may face if they put a particular plant in their gardens.

Recruit plant fanatics as allies in the marketing process. They most likely have friends who are interested in gardening. Their gardens can act as showcases for your product. Encourage them to spread the word about what new perennials work for them. Imagine the free publicity you could get by giving them those plants. You can't buy more credible, effective advertising than endorsements from successful gardeners in the community, to whom others look to as trend-setters.

Formula For Success: Marketing Forced Perennials

1. Divide your customers by how often they buy plants, how much they know about your products and gardening, and how much they enjoy it.

2. Recruit plant fanatics as your allies. Learn from them which plants do well in their gardens and ask them questions about what problems or challenges they have faced with a particular plant.

3. Position perennials as the spice, or accent, to a landscape rich in annual color.

4. Show less experienced gardeners how to coordinate perennials with annuals or flowering shrubs.

5. Build perennial awareness outside the garden. Market the added value of enjoying some perennials indoors by emphasizing their use in homes or businesses.

2. Market The Use

Not everyone is as passionate about their plants as master gardeners. But they might get enthusiastic if we market to them in a way that appeals to how they garden.

Perennials are great accents to annuals. One benefit of perennials is that most gardeners won't have to replant each year to get that splash of color.

Position perennials as the spice of the garden. People who focus on decorating with color in the landscape can relate to

Figure 2.

Figure 2. Michigan State University's trial area for forcing perennials at the time of planting (left) and at week 6 (right).

this. The accent should be used in smaller amounts to bring focus or attention to a point or object.

Show novice gardeners exactly how to use perennials in a demonstration garden. While we can put plant combinations together easily, it is a real challenge for less experienced gardeners.

Department stores put outfits together on their mannequins to show people how to coordinate clothes. We can adapt the same principle to marketing perennials. Show the less experienced gardener how to coordinate perennials with annuals or flowering shrubs.

Will everyone buy perennials? Probably not. The National Gardening Association's annual survey of gardening revealed that only 20% of the 105 million households bought perennial plants last year (25% bought annual plants). While not everyone buys annuals or perennials, we still have a long way to go before the market is saturated.

3. For Inside And Outside

Michigan State University (MSU) researchers have found some perennials can be used as potted plants indoors. Just think of the added value a perennial has as a table decoration *and* a garden plant.

Market research shows that most consumers recognize traditional perennials, such as rudbeckia and salvia, as those that are found in gardens. We also found that lesser-known perennials, like campanula 'Blue Clips,' were perceived as more similar to traditional potted indoor flowering plants. Consumers accurately perceived a chrysanthemum as a plant that can be used indoors or outdoors.

American Floral Endowment®

The American Floral Endowment helps fund perennial research at Michigan State University.

The challenge to perennial researchers now is to identify potential plants that perform well inside the home for a short time, and then can be planted outdoors. At MSU, we placed forced plants of leucanthemum 'Snow Caps' (Figure 1a), campanula 'Blue Clips'(Figure 1b), echinacea 'Bravado,' and aquilegia 'Cameo' in a simulated shipping environment for 3 days and then in a simulated retail display for an additional 7 days. Some species performed better than others, but the experiment gave us preliminary results for plants that should be further tested.

Another concern arises when we market these forced perennials. Some professionals and avid gardeners are suspect of what forcing will do to the natural flowering pattern of the perennials. While we have seen no detrimental effects for several years, funding from the American Floral Endowment has enabled MSU researchers to investigate this, as well.

Plants from the experiment were also planted outdoors in full-sun garden beds on the MSU campus. After only 1 year in the ground, we can see they have performed quite well (see Figure 2). Many of the plants that were in flower at planting June 1 had successive flowering periods. The real test will come as we monitor flowering next year. Yet, we have seen no ill effects to date on garden performance.

Research on marketing forced perennials indicates consumers know these plants grow outside. Marketing the added value of enjoying some of these perennials indoors, before they are planted outside, presents a real opportunity for growers. Will consumers pay more for this added value? Research in 2000 will give us some additional insight.

For now, perennial marketers should focus on building awareness of perennials and their uses in and around the home or business. We can market perennials as the spice, or accent, added to a landscape rich in annual color. We also can market perennials as a substitute for annual color in the landscape, perhaps combined with interesting grasses, colorful flowering shrubs, or against a backdrop of evergreens. Market the color, not the plant, that comes from a well-tended garden with perennials. **GG**

About the author: Bridget Behe is an associate professor, Department of Horticulture, Michigan State University, East Lansing, MI 48824. Sources include the *Index of Garden Plants* and *Ball Perennial Manual*.

– Crop By Crop –

FORCING PERENNIALS

Florel may be a useful tool in controlling potted herbaceous perennial crop height.

by ***TAKAHIRO HAYASHI, ROYAL D. HEINS, ARTHUR C. CAMERON,*** *and* ***WILLIAM H. CARLSON***

CONTROLLING plant height and manipulating the flowering date can be difficult in the commercial production of potted herbaceous perennials. Height control is important because tall plants can become top-heavy and floppy and therefore more expensive to ship. Manipulating the flowering date is also important to avoid overconcentration of flowering plants on a single date and extend shipping and sales beyond the natural flowering period.

Ethephon, an ethylene-releasing compound sold under the trade name of Florel, has been successfully used to retard stem elongation and manipulate the flowering date of several plants such as geraniums and New Guinea impatiens. Ethephon affects plant height following absorption because it breaks down into ethylene, and one response to ethylene in plants is the reduction of cell elongation.

Ethephon through ethylene release can also inhibit flower initiation and cause abortion of young flowers of many species.

Many herbaceous perennial species flower within a limited period of time when forced in a greenhouse or outdoors. If ethephon could be used to successfully delay flowering of herbaceous perennials without completely eliminating flowering, this might permit growers to schedule shipping past normal flowering dates.

Methods

We applied Florel to eight plant species to determine if it might effectively regulate plant height and flowering. Species treated were *Achillea millefolium* 'Weser River Sandstone,' *Coreopsis verticillata* 'Moonbeam,' *Echinacea purpurea* 'Bravado,' *Leucanthemum* x *superbum* 'Thomas Killen,' *Liatris spicata* 'Kobold,' *Monarda didyma* 'Blue Stocking,' *Phlox paniculata* 'Mt. Fuji,' and *Physostegia virginiana* 'Summer Snow.'

Plants in eight-inch pots were forced in a fan-and-pad cooled greenhouse starting in mid-June under natural light plus a four-hour night interruption by high-pressure sodium lamps. Sprays of Florel at 500 and 1,000 ppm were applied once, twice, or three times at two-week intervals by using a hand-held sprayer to uniformly wet plant foliage and stems.

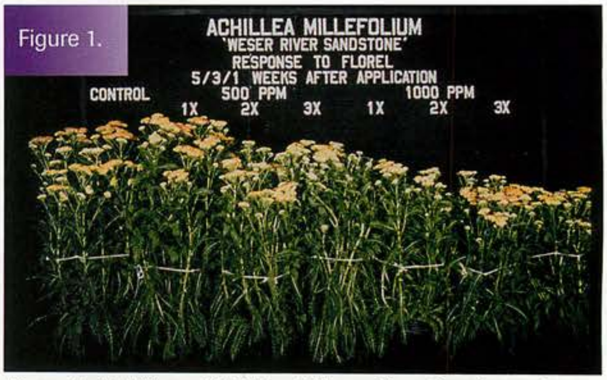


Figure 1. ***Achillea millefolium*** **'Weser River Sandstone' showed about 20% height reduction by Florel treatment. Number of inflorescences per pot was increased an average of 20% by Florel.**

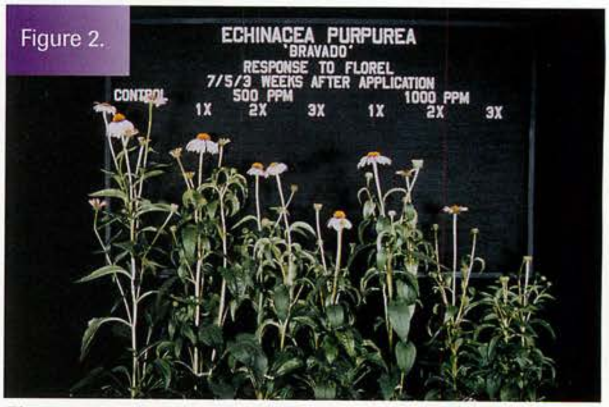


Figure 2. ***Echinacea purpurea*** **'Bravado' responded dramatically to Florel. Florel reduced plant height about 40% and delayed flowering up to six days.**

Flowering Time And Plant Height

The effects of Florel on plant height and flowering varied among species. Florel reduced height at first flower of achillea (Figure 1), echinacea (Figure 2), leucanthemum (Figure 3), monarda (Figure 4), and physostegia (Figure 5). Plant height for these species was reduced 23%, 42%, 46%, 40%, and 46%, respectively, when Florel was applied three times at 1,000 ppm.

Final plant height of liatris (Figure 6) decreased up to 28%, but there was no significant difference between the mean value of treatments and that of the control because some treated plants responded only slightly to Florel.

Overall, Florel had little effect on flower timing of the tested herbaceous perennials. Spraying Florel three times at 1,000 ppm only delayed flowering of echinacea, monarda, and physostegia by six, seven, and nine days, respectively. Although not statistically significant, flowering time was delayed up to five and seven days in phlox (Figure 7) and liatris, respectively, on plants sprayed three times at 1,000 ppm.

Generally, the magnitude of Florel's effect on plant height and flowering time was in proportion to the applied dose. Height and flowering were increasingly reduced and delayed as application number and concentration increased.

Flower Number

Florel has been used as a branching agent for decades because it promotes axillary shoot development without killing the apical meristem or growing point. In this experiment, Florel promoted or suppressed branching, depending on the species. The number of inflorescences per pot was increased by Florel application in achillea, coreopsis, and phlox, while it was decreased in echinacea, leucanthemum, monarda, and physostegia.

Achillea, coreopsis (Figure 8), and leucanthemum had already initiated inflorescences when first sprayed with Florel at the experiment's start. In contrast to its effects on plants like geranium and New Guinea impatiens, Florel did not abort these flowers, even when applied three times at 1,000 ppm.

Flower Size

Florel reduced the inflorescence size in echinacea and leucanthemum (Figure 9) in proportion to the amount applied. Three applications of Florel at 1,000 ppm resulted in poor-looking leucanthemum plants with small inflorescences.

Plant Uniformity

Liatris, echinacea, leucanthemum, and physostegia had individual plants that did not respond to Florel. We speculate that the nonresponse was caused by nonuniform genetics among plants in these species. It is possible that lack of genetic uniformity may result in variable responses to Florel among plants of the same cultivar.

Plant Form

The amount of Florel a plant absorbs from a spray treatment is a function of surface area of the plant body, that is, total leaf area. Therefore, besides concentration and the number of applications, plant form and application method may be important. Plants with small leaves like coreopsis 'Moonbeam' may absorb less solution, which may partly account for the small stem-elongation response to Florel application.

Phytotoxicity

Florel at 1,000 ppm caused severe phytotoxicity on the young foliage of monarda (Figure 10); therefore we do not recommend Florel application to monarda. Phytotoxicity was not observed on other plant species.

Application rates and frequency may be altered based upon the differences in species, desired time to flower, and final plant height as well as climate and culturing methods. Our suggested application dose and the factors or responsiveness to consider are as follows:

Application concentration. If you do test Florel on herbaceous perennials under high-temperature summer conditions similar to that of our experiment, we suggest the application rate initially be made at 1,000 ppm

Figure 3. Final plant height of *Leucanthemum* x *superbum* 'Thomas Killen' was decreased up to 46% by Florel treatment. See also Figure 9.

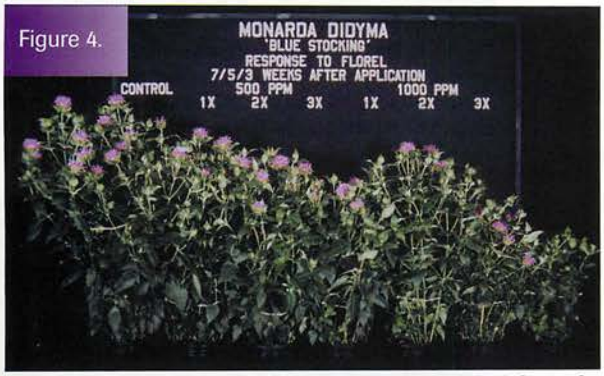


Figure 4. Florel was useful for regulating plant height and flowering of *Monarda didyma* 'Blue Stocking.' Number of inflorescences per pot was greatly decreased by Florel.

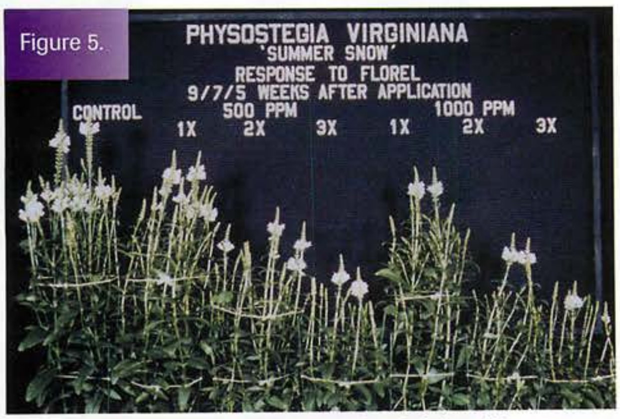


Figure 5. Plant height of *Physostegia virginiana* 'Summer Snow' decreased linearly with increasing concentration and the number of Florel applications. Flowering was delayed up to 10 days in proportion to the number of Florel applications, regardless of concentration.

and then adjusted according to your evaluation. Although not evaluated, concentrations higher than 1,000 ppm may be necessary to control the height for achillea and phlox, while lower concentrations may be suitable to increase attractiveness for leucanthemum and monarda.

Because these experiments were conducted during summer, we do not know the application's effects during winter and spring. Rates lower than 1,000 ppm should be tested during these seasons.

Application Frequency. A two-week interval between Florel applications was suitable as judged from our observations on Florel's effect on stem elongation. We do not know if longer-interval applications at a higher concentration or short-interval applications with a lower concentration will work equally well.

Florel's Fate

Our initial goals were to determine if Florel would delay flowering and decrease stem elongation in herbaceous perennials. Even with three 1,000- ppm applications, flowering was not delayed more than nine days for any species. Therefore, we do not believe Florel, at least at the rates and frequency applied, will be a feasible method of delaying flowering in these herbaceous perennials as it is in crops like zonal geraniums or New Guinea impatiens.

Stem elongation in most species tested was reduced by Florel applications. Therefore, Florel could be used as an alternative to other growth retardants for height control. High dosages, however, must be avoided because flower size can be adversely affected in some species (Figure 9). **GG**

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Figure 6. Response of *Liatris spicata* 'Kobold' to Florel was highly variable among plants. Time to flower tended to increase as Florel application dosage increased. Although not statistically significant, final plant height tended to decrease as Florel dose increased.

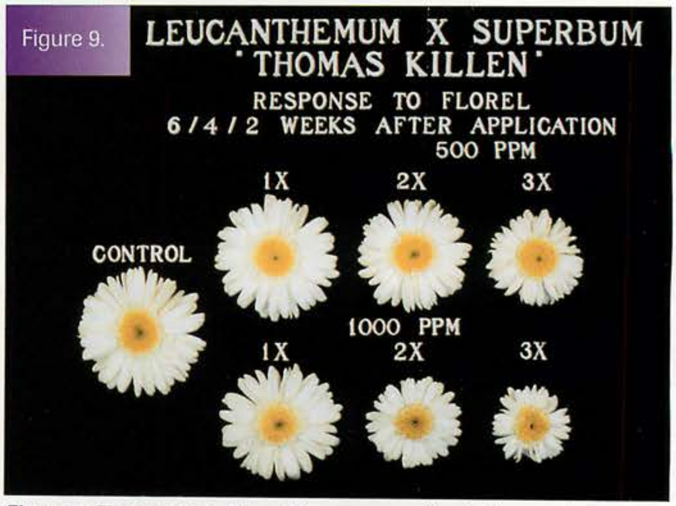

Figure 9. Florel reduced the inflorescence size in *Leucanthemum* in proportion to the amount applied.

Figure 10. Florel at 1,000 ppm caused severe phytotoxicity on the young foliage of *Monarda*.