– Crop By Crop –

FORCING PERENNIALS

Species: *Achillea* spp.
Common Name: Common Yarrow


Figure 1a.


Figure 1b.

Figure 1a. Achillea's vibrant colors add dramatic contrast in the garden. *Photo courtesy of Laura Coit.* Figure 1b. Each plant continuously changes in color and texture throughout the growing season. *Photo courtesy of Marlene Cameron.*

by ***ERIN NAUSIEDA, LOUIS SMITH, TAKAHIRO HAYAHSI, BETH FAUSEY, ARTHUR CAMERON, ROYAL HEINS,*** *and* ***WILL CARLSON***

ACHILLEA species are multi-purpose plants that have been reportedly utilized since 1200 B.C. when Achilles, a great warrior of the Trojan War, used the herb to heal his soldier's wounds.

Today, the species are grown for medicinal teas, beer, liqueurs, ingredients in hair shampoo, sheep grazing, and even a turf grass substitute for residential lawns. The most common uses of Achillea, however, are for cut flowers and ornamental garden value in the landscape industry (Figures 1a, b).

Achillea, commonly known as yarrow, fernleaf yarrow, milfoil, or sneezewort is in the Asteraceae (Compositae) or Sunflower family. Species are hardy in USDA zones 3 to 8, and are naturally found in pastures, meadows, along roadsides, and sand dunes throughout the northern hemisphere.

Though there are nearly 100 Achillea species, only a few are used as ornamental plants in the U.S. horticulture trade. The most popular species in landscapes today include *A. millefolium, A. filipendulina, A. ptarmica,* and *A. tomentosa.*

The height of the ornamental

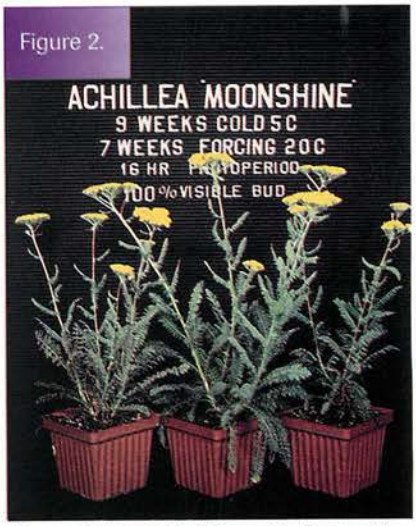


Figure 2.

Figure 2. Many Achilleas, including the cultivar 'Moonshine,' are well suited to container production and make attractive flowering potted plants. *Photo courtesy of Leslie Finical.*

species in cultivation range from a few inches to a few feet. *A. millefolium* and *A. filipendulina* selections generally form upright clumps with multiple basal rosettes depending on the species. Achilleas spread by rhizomes and some can be overly aggressive; however, the best cultivars spread slowly and are very manageable.

Achilleas prefer full sun and well-drained to dry soils. With excess nitrogen and moisture, most species tend to become leggy and invasive. In climates where night temperatures typically remain below 70°F, plants produce stronger stems and don't require staking.

New cultivars are continually being released and there is great variety in flower color from pale cream to vibrant red. The new millefolium hybrids, such as 'Fireland,' 'Galaxy,' and 'Apple Blossom' are especially attractive.

The texture and color of Achilleas continuously change from bud formation to flower senescence. Achilleas also demonstrate diverse foliage colors from soft gray-greens to intense deep-dark greens, which add great color contrasts to any garden display.

We have conducted research on six different species and nine different cultivars of Achillea (Figure 2). The following summary covers most of the *Achillea spp.* we have tested.

1. Propagation

Species and cultivars that are propagated from seed will bulk in cell trays and pots quite uniformly, but the flowers do not usually come true to color and the plants may vary in appearance. Millefoliums and filipendulinas tend to be weedy when propagated from seed.

The most popular selections of *Achillea spp.* are clones and thus must be propagated asexually. Rooting of stem cuttings is the method of choice for plug production, though division can be used.

For maximum stem cutting production per stock plant of Achillea 'Moon-shine,' it is best to grow stock plants under photoperiods of less than 12 hours, though cuttings taken from plants grown under long days root well. Under short photoperiods, we have observed that stock plants of some Achillea cultivars produce numerous lateral shoots from the crown (Figure 3a, b, and c).

Keep in mind that cuttings in propagation are very susceptible to rot and mist frequency should be kept to a minimum. Remove cuttings promptly from mist once rooted.

2. Plant Size

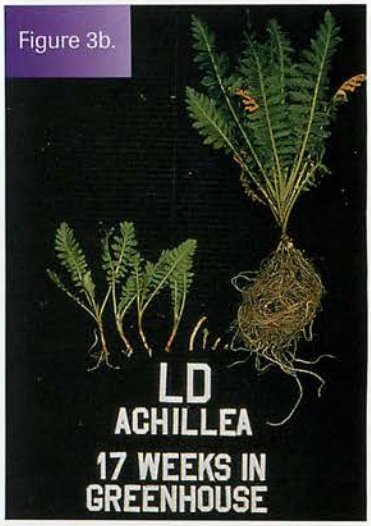
Plugs from 32- to 128-cell trays with three to five nodes per plant are appropriate for a five-inch pot. Juvenility has not been a problem with any of the vegetatively propagated cultivars tested. Bulking before a cold treatment is not required but is desirable to fill a five-inch or larger pot.

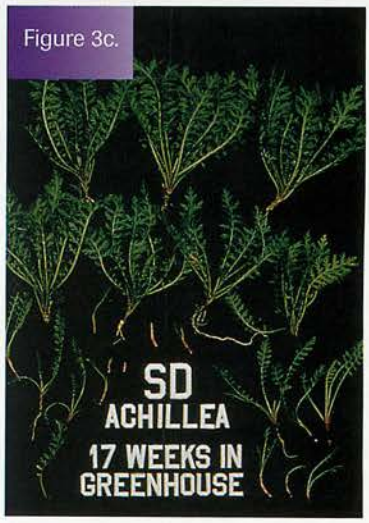
3. Cold Treatment

A. tomentosa 'King Edward VIII' was greatly influenced by a cold treatment. Without cold, most 'King Edward VIII' flowered after 15 to 20 weeks under a 16-hour high pressure sodium (HPS) photoperiod and easily filled five-inch pots, gracefully hanging over the pot and forming nice, soft mounds.

After cold, plants flowered within six weeks but lacked adequate vegetative growth and flower number. 'King Edward VIII' will benefit from bulking before the cold treatment. In our experiments, a cold treatment is given at 41°F (5°C) in controlled temperature coolers under florescent lights.

None of the other Achillea cultivars we have tested appear





Figures 3a, b, and c. Achillea plants grown under nine-hour short day (SD) and long day (LD) photoperiods for 17 weeks. SD photoperiods increased basal shoot development and vegetative growth for maximum stem cutting production. *Photos courtesy of Beth Engle.*

to require a cold treatment for flower induction (Figures 4a, b, c, and d; Table 1). On most Achilleas, there was an increase in the number of lateral shoots following cold treatments. This may have been due to a direct effect of cold or to increased light levels. It is also possible that cold treatments reduce apical dominance. *A. filipendulina* 'Gold Plate,' however, actually produced fewer lateral shoots per plant after 15 weeks of cold. This was due to the dramatic decrease in time to flower, which gave the lateral shoots less time to develop. Also, *A. filipendulina* cultivars naturally have few or no basal shoots (Figure 5).

4. Photoperiod

All Achillea cultivars tested are facultative long-day plants, which means they flower under all photoperiods, but flower more rapidly, consistently, and uniformly under long days (Table 1). Under nine-hour photoperiods, no flowering occurred without cold for any cultivar tested except 'Apple Blossom' and 'Paprika.'

Even after cold, low flowering percentages (50% on average) were observed under nine-hour photoperiods. Short days, however, increased vegetative growth and lateral shoot development on all the cultivars tested. Avoid constant 24-hour lighting becausde it tends to cause rapid bolting with insufficient plant bulking.

We have tested 'Anthea,' 'Corona-tion Gold,' 'Moonshine,' and 'Paprika' under 10-, 12-, 13-, 14-, 16-, and 24-hour photoperiods and a four-hour night interruption from 10 p.m. to 2 a.m. at 68°F (20°C) (Figure 6).

'Paprika' had high flower percentages (90% to 100%) under every photoperiod with and without cold. But 'Anthea,' 'Coronation Gold,' and 'Moonshine' flowered best only under 16-hour and four-hour night interruption photoperiods.

5. Media, Fertilization, And Irrigation

We attempted to maintain pH levels between 5.8 and 6.2. A fertilizer solution was applied with each watering application containing 100 to 150 ppm N, 10 to 20 ppm P, and 100 to 150 ppm K. The constant fertilizer applications appear to increase legginess and the need for staking. As mentioned previously, *Achillea spp.* prefer less fertile soil to maintain their natural height in the garden. Also, the media remained fairly moist throughout the experiment, which contributed to an increase in plant height.

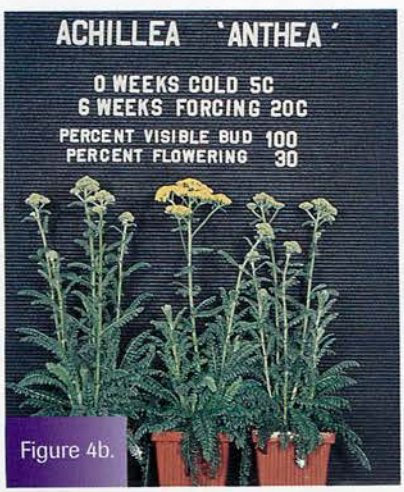
We suggest that Achilleas be grown with less nitrogen and water. *Achillea spp.* are dry-land plants and not typically tolerant of intensely wet conditions. Disease problems may arise from over-watering, especially if water collects on the leaves.

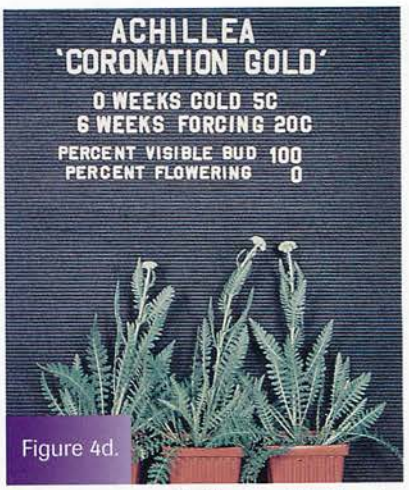
Botrytis is common on cultivars derived from 'Taygetea' that possess more leaves at the base of the plant. Also, 'The Pearl' is very susceptible to powdery mildew.

6. Lighting And Spacing

Achillea spp. are full sun, high light plants. In many cases, gray foliage is indicative of plants that are adapted to high light, such as 'Anthea' and 'Moonshine.' During Michigan winters, we have found that supplemental lighting improves flower quality and induces more lateral shoots for all species tested (Figure 7). Increasing supplemental light from nine to 16 hours per day increased plant height with 'Galaxy,' 'Hope,' and 'Terra Cotta' (Table 1).

Achillea spp. may be placed pot to pot when first brought into the greenhouse, then spread out after growth initiates.





Figures 4a, b, c, and d. Many Achillea cultivars develop rapidly on the bench following exposure to cold. Plants of 'Anthea,' 'Paprika,' and 'Coronation Gold' are relatively small two weeks after planting (a), but are well developed after six weeks of forcing (b, c, and d). ***Photos courtesy of Takahiro Hayashi.***

Some cultivars, such as 'Paprika,' develop multiple lateral shoots and require more space. On the other hand, 'Hope' and 'Terra Cotta' are narrow upright growers and require less space per pot. Keep in mind, however, that closer spacing can increase plant height and reduce lateral branching.

7. Plant Height Control

Many Achillea cultivars naturally grow to four feet in the garden. In the greenhouse, plant height was both cold and photoperiod dependent. Most cultivars tested were six to eight inches (15 to 20 centimeters) shorter after a 15-week cold treatment, com-

Table 1. **Forcing Comparisons and Recommendations for Achillea**

Cultivar	Cold recommended for 100% flowering and optimal growth	Photoperiod required for 100% flowering and optimal growth	Responses to recommended forcing temperatures					Comments
			Temp. (F°)	Plant Height (cm)	Days to visible bud	Days from visible bud to flower	Weeks to flower	
A. aegyptiaca 'Taygetea'	Not tested		68	35-45	15	25	6	Small, dull yellow flowers. Produces multiple flowering laterals, but too tall and weedy for a five-inch pot.
A. clypeolata x 'Taygetea' 'Anthea'	0		64-68	35-45	27	21	7	Attractive gray-green leaves and pale-yellow flowers. Soft-textured plant. Great in the garden, but wilts easily in warm, sunny greenhouse conditions.
A. clypeolata x 'Taygetea' 'Moonshine'	0		68	24-45	10	15	3.5	It's very similar in appearance to 'Anthea,' but the flowers are a brighter yellow. The multiple lateral shoots make for a nice potted and garden plant.
A. filipendulina 'Gold Plate'	0		68	55-65	22	31	7.5	Large, bright yellow flowers. Too tall for a five-inch pot; PGRs are recommended. Small leaf mass with few leaves at each node. Great for cut flowers.
A. filipendulina x *clypeolata* 'Coronation Gold'	0	↑	68	45-55	30	32	9	Gray-green leaves. Gold-yellow flower heads three to four inches across. PGRs may help increase shoot count and control height. Low leaf count.
A. millefolium x 'Taygetea' 'Apple Blossom'	0	Long Days	68	25-35	17	22	6	Bright green leaves that are more severely segregated. New flowers possess a deep rose color, fading to a pale, pinkish-white. Attractive potted plant.
A. millefolium x 'Taygetea' 'Fireland'	0	↓	68	50-60	34	28	9	Dark green foliage with attractive red to orange flowers. Too tall for a five-inch pot; PGRs are recommended. Staking is needed.
A. millefolium x 'Taygetea' 'Galaxy'	0		68	30-40	37	24	9	Pink flowers and bright green foliage. Numerous nodes and lateral shoots. Plants in a 16-hour HPS photoperiod were too tall for a five-inch pot.
A. millefolium x 'Taygetea' 'Hope'	0		68	35-45	22	24	6.5	Pale yellow flowers. PGRs are recommended to control height. Displayed a large number of lateral shoots under each photoperiod tested.
A. millefolium x 'Taygetea' 'Paprika'	0		68	45-55	30	21	7	Multiple shoots with bright green leaves and deep red flowers. Increased light equals increased plant height. Susceptible to Botrytis.
A. millefolium x 'Taygetea' 'Terra Cotta'	0		68	45-55	25	25	7	Flowers seemed more yellow than terra cotta in color in greenhouse. Tall and slender with laterals growing close to one another. PGRs recommended.
A. ptarmica 'The Pearl'	0		68	40-45	5	26	4.5	Cream-colored double flowers with finely toothed linear leaves. Very susceptible to powdery mildew in wet soils and shady conditions.
A. tomentosa 'King Edward VIII'	Yes, minimum duration unknown	Day neutral after cold	68	10-15	18	23	6	Low-growing rock garden plants with pale yellow flowers. Bulking is recommended to fill a five-inch pot. Needs good drainage.

pared to the plants that received no cold. Also, long-day plants were on average four inches (10 centimeters) taller than the short-day plants.

Since long-day photoperiods are necessary for 100% flowering, growth retardants are recommended for the taller cultivars such as 'Hope' and 'Terra Cotta.' We conducted a preliminary experiment on *A. millefolium* 'Summer Pastels' using A-Rest, B-Nine, Bonzi, Cycocel, and Sumagic. Of the five growth regulators, A-Rest, B-Nine, and Sumagic reduced plant height, while the other two chemicals were not effective.

8. Temperature And Crop Scheduling

In the garden, most Achilleas will perform well in USDA zones 3 to 7 or 8. Plants grown in warmer areas should probably be treated as annuals because disease problems are common at higher temperatures and humidity. *Achillea spp.* do not seem to tolerate high temperatures in the greenhouse as well because the plants tend to easily wilt under hot sunny conditions.

We recommend forcing between 64°F and 68°F (18°C and 20°C) to achieve optimum plant quality and flower timing. Based on their research results, University of Georgia researchers also recommend cool temperatures for forcing 'Summer Pastels.' The cultivars we have tested should flower in four to nine weeks when forced between 64°F and 68°F (18°C and 20°C).

Because many good cultivars of Achillea do not require cold for best performance, it is possible to develop "quick crop" production schedules. Cuttings can be taken from stock plants and moved directly into production after rooting, bypassing the cold treatment altogether. Salable plants may be produced in as little as nine weeks from harvest of the cuttings.

In addition, fuller plants can be produced by bulking rooted cuttings under SD photoperiods for several weeks prior to providing LD photoperiods for flowering.

Figure 6.

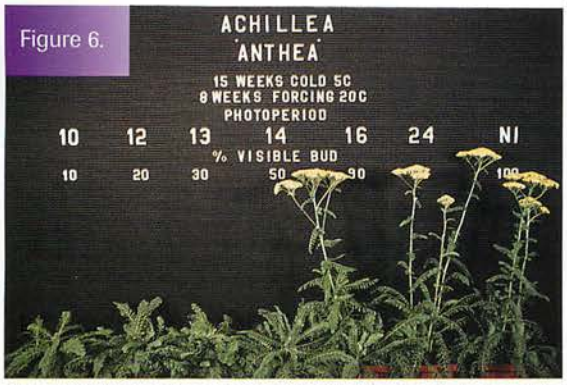


Figure 6. 'Anthea' required at least a 14-hour photoperiod to achieve 100% flowering in the shortest time.

Figure 7.

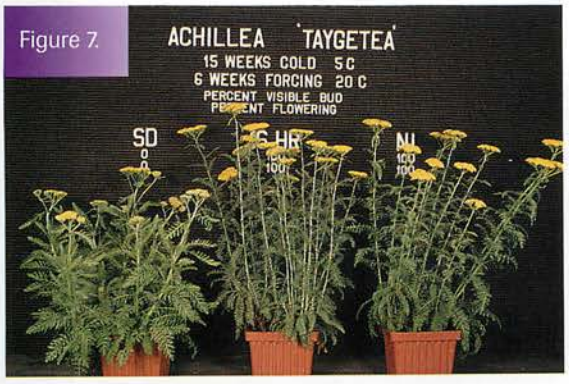


Figure 7. Achillea 'Taygetea' plants grown under a 16-hour photoperiod with supplemental lighting had sturdy, upright stems, with more lateral shoot development than plants under other treatments.

9. Disease And Insect Pests

Achilleas are usually quite resistant to most diseases and insects in the greenhouse and the garden. But as mentioned previously, 'Taygetea' hybrids such as 'Moonshine' and 'Apple Blossom' are susceptible to Botrytis and other fungal diseases under high temperature and humidity environments. Achillea 'The Pearl' was very vulnerable to powdery mildew. No persistent or detrimental insects were observed.

Formula For Success: Achillea

1. Choose a superior clone.

2. Use rooted cuttings with at least two to three nodes.

3. Grow under short days for up to several weeks to increase lateral shoots.

4. Force between 64°F and 68°F (average daily temperature). Avoid higher temperatures.

5. Force with 16-hour photoperiods or with night interruption.

6. Water and fertilize sparingly to limit disease and plant height.

7. Ship at first flower.

10. Postharvest Concerns

Shipping should begin as soon as the first flower opens. Most cultivars continue to flower for three or more weeks in the greenhouse, and typically bloom throughout the growing season in the garden.

Deadheading is recommended in the garden to encourage lateral shoot growth. If flowers are grown for fresh arrangements, they may be picked when in color. The flowers may be picked at any stage before pollen sets if they are destined for dried arrangements. The flowers don't possess the most attractive scent, but it dissipates when the flowers dry. **GG**

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– Crop By Crop –

FORCING PERENNIALS

Species: *Anemone hupehensis*
Common Name: Anemone or Windflower


Figure 1a.


Figure 1b.

Figures 1a, 1b. *Anemone hupehensis* in flower.

by ***JOAQUIN A. CHONG, ROYAL HEINS, EMILY CLOUGH, ARTHUR CAMERON,*** *and* ***WILL CARLSON***

ANEMONE is a diverse group of perennial species produced as cut flowers and potted plants. A member of the Ranculaceae family, anemone can be divided into three categories by flowering and root morphology.

The first category includes spring-flowering anemones that have underground, knobby, tuberous, bulb-like rhizomes. The second includes those that flower in early summer and have tuberous roots. The third category, to which our recommendations apply, includes those that flower between summer and autumn and have fibrous roots (Figure 1).

Anemone flowers sit on elegant, tall shoots that emerge from the main apical meristem. After flowering, leaves and shoots die back and decompose in winter. Roots with buds that produce shoots will emerge during the following spring and summer. These shoots can flower the first year after they emerge.

1. Propagation

Root cuttings prove to be the best method of anemone propagation because shoot cuttings do not normally root. A root cutting is a propagation technique by which adventitious buds develop from roots that have been cut into individual pieces and planted upright in a growing medium. Three root cutting techniques allow efficient anemone propagation.

In the first method, mother plants are grown in open fields or one-gallon containers outside the greenhouse with full sun exposure for a summer season. In the fall, the soil is removed and the roots are cut into one-inch pieces and placed vertically in a flat or plug tray for shoot regeneration. Roots need to be kept moist until the adventitious buds form

Figure 2. Root buds emerge from a root.

and begin to grow. Plants that develop from these buds can then be transplanted to a plug or container.

The second technique involves "scooping" the mother plant and leaving the separated single roots in place. New buds will then generate from each thick root (Figure 2). After the buds form, the shoots must be separated and transplanted while leaving the roots attached.

Removing the anemone plant from the pot and cutting the root mass and soil into one- to two-inch layers while keeping layers moist as shoots regenerate is part of the third method (Figure 3). Later, shoots are separated, leaving the roots attached, and transplanted into a plug tray.

Most references suggest the best time to take root cuttings is during late winter or early spring, before the plants develop.

For proper root-bud generation, roots are placed with the top ends up because they have polarity and buds may not regenerate if they are planted upside down. Cutting the roots at the top with a straight cut and at the bottom with a slanted cut will help you place them correctly when planting.

Our experiments show that if mother plants are grown in a 68°F greenhouse, they should be at least 15 weeks old before root cuttings are taken. Because they yield more viable root cuttings, older plants with thicker roots work better. To grow a five-inch potted plant, 20 or more weeks of growth at an average daily temperature of 68°F are adequate.

Anemones also can be propagated by division, but the plants will be larger and there will be a smaller yield than crops generated by root propagation. Seed propagation is also possible, but progeny are neither uniform nor true to type.

2. Plant Maturity

Plants undergo different phases during their life cycles. During the juvenile phase, even under the proper environmental conditions, plants will not flower or respond to flower induction by cold or photoperiod. After the juvenility phase, plants can be induced to flower under proper environmental conditions.

To deliver these conditions that force plants to flower, we must know when the plants are mature. Counting the number of leaves or nodes formed after the cotyledons is one way to estimate maturity in seed-propagated plants. The number of nodes required to overcome juvenility varies from plant to plant and can be determined only through research. Some plants give natural indications of maturity by changing leaf morphology, like ivy (*Hedera helix*).

Using leaf counts to estimate the maturity of plants developing from root cuttings is difficult, but anemones propagated by root cuttings undergo a "reversion to juvenility" (Figure 4). Juvenile anemones initially produce juvenile leaves that have single lobes. As plants mature, subsequent leaves show signs of maturity by becoming trilobed (Figure 5). After these trilobed leaves form, plants can then be induced to flower.

3. Cold Treatment

Anemone hupehensis does not have an obligate cold requirement for flower induction, but we recommend at least six weeks at 41°F (5°C). Cold promotes more vigorous growth, increases flower uniformity and numbers, and slightly reduces the time needed to flower.

The best time to deliver cold is when the plant's root system is thick and well established in a plug tray. The thicker the roots, the better. As a rule, plants with healthy, yellow roots that are more than $^1/_8$-inch thick are ready for cold.

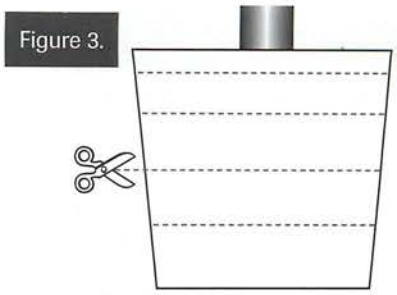

Figure 3. The layer root-cutting method.

Plants often lose leaves during cooling, which is not a problem as long as the roots are healthy. Thick new root buds will emerge during forcing.

4. Photoperiods

Anemones are obligate long-day

Formula For Success: Anemone

1. Use a well-drained medium and keep plants evenly moist. Anemones are susceptible to Rhizoctonia, fungus gnats, and Pythium.

2. If propagating plants, select clean, disease-free stock and plant roots in a three- to $3^1/_2$-inch tall plug cell to increase drainage by gravity.

3. For vegetative growth, grow plants under photoperiods less than 13 hours.

4. Bulk small plants for 12 to 15 weeks to increase root mass. When thick roots are present, treat with cold for at least six weeks at 41°-45°F (5°-7°C) before forcing. Photoperiods during cold could be the equivalent of natural daylength or nine hours of light if plants are cooled in a cooler.

5. Keep greenhouse temperatures at or below 68°F (20°C) during forcing.

6. Expose plants to at least 13-hour photoperiods or night-interruption lighting from 10 p.m. to 2 a.m. to promote flowering.

7. Provide supplementary lighting with high-pressure sodium lamps if bulking or forcing during midwinter.

plants, so flowers will be initiated only when plants are exposed to photoperiods of at least 13 hours (Figure 6).

Long days can be provided as a day extension or a four-hour night interruption from 10 p.m. to 2 a.m. by using incandescent or high-pressure sodium lamps. Incandescent lamps generally cause stem elongation and lower-quality plants. To bulk anemone, place plants under photoperiods of less than 13 hours.

Figure 4. View of anemone root buds with small leaves emerging from a root cutting. Leaves are difficult or impossible to count in this stage.

5. Lighting And Spacing

Crowded plants will have poor quality. Plants should be spaced according to size, allowing light to penetrate to the lower leaves. Mature plants in five- or six-inch containers require about one square foot of space each.

6. Medium, Irrigation, And Fertilization

Start with a well-drained medium. Proper watering is crucial for successful anemone production. When anemones become water stressed, leaf-edge burn occurs. Also, if plants are continuously wet, Pythium root rot develops, killing the roots and the plants.

When watering, consider the plant size, stage of development, medium, and environmental conditions like humidity, air flow, light intensity, and temperature. Large plant size, late developmental stage, low humidity, rapid air flow, high light intensity, and high temperatures generally increase water requirements.

Keep root cuttings moist, not wet, during propagation. Plug trays that are deeper than they are wide increase water runoff because of gravity. To avoid leaf-edge burn, increase watering frequency to keep roots continuously moist, but not wet, as shoots develop. Closely monitor the watering of recent transplants without established root systems.

Although plants are susceptible to leaf burn caused by water stress, it is natural for anemone to lose some lower leaves as plants age. As new leaves form, the plant's base enlarges, breaking the lower leaf petioles and killing the leaves (Figure 7).

Use a balanced fertilizer to provide moderate nourish-

Table 1. ***Anemone hupehesis* Production Schedule**

Growing time	*Cultural practice*	*Temperature*	*Photoperiod*
> 20 weeks	Stock plants	68°-72°F (20°-22°C)	<13 hours of light or >13 hours, but if flowering occurs, cut off flower shoots
12 to15 weeks	Grow plants from root cuttings to mature leaves	70°-75°F (21°-24°C)	<13 hours of light
	- OR - *Purchase plugs*		
≥ six weeks	Cold treatment	35°-45°F (2°-7°C)	Natural daylength or nine hours of light in cooler
	Begin Forcing		≥16 hours or four-hour night interruption
↓ ↓ ↓ ↓ 57°F (14°C) = 16 weeks to flower	↓ ↓ 64°F (17°C) 13-14 weeks to flower	↓ 68°F (20°C) 12-13 weeks to flower	**Visible bud to flower** 57°F (14°C) - 42 days 63°F (17°C) - 40 days 68°F (20°C) - 35 days

Figure 5. Trilobed and monolobed leaf.

ment. Constant fertilization with nitrogen at 100 to 200 ppm is adequate. The medium's pH should be kept between 5.8 and 6.4. Anemone are very susceptible to iron deficiency. We battled foliar chlorosis until we made a one-time application of 30 ppm iron from iron chelate.

7. Plant Height Control

We have seen considerable plant height variability in our experiments, especially in the flower shoots. In our trials, the first flower opened when the plant was 13 to 16 inches (30 to 40 centimeters) tall, although plants grow considerably taller outside under good moisture. We have not tested any height-controlling growth regulators on anemone.

8. Temperatures And Crop Scheduling

Anemone hupehensis performs best at cooler temperatures. Temperatures above 68°F (20°C) caused delayed flowering, fewer flowers, and short plants. Plants grown at 68°F (20°C) flowered in 12 to 13 weeks from the start of long-day treatments. Plants at 63°F (17°C) took 13 to 14 weeks to flower, and plants at 57°F (14°C) took around 16 weeks to flower. We suggest forcing at or below 68°F (20°C) for the highest quality plants.

9. Disease And Insect Pests

Rhizoctonia has been our primary disease problem. The fungus attacks the plant's lower stem, causing crown rot and above-ground collapse as the water and nutrient-conducting vessels are destroyed (Figure 8). Anemone leaf stipules and petioles form a small cavity capable of collecting water, increasing the chance of Rhizoctonia infection.

Clean stock and proper watering is essential for Rhizoctonia control, and any plant showing disease symptoms should be thrown away. When transplanting anemones into pots, soil around the shoots should be removed until the crown is exposed. This will allow the shoots to dry as quickly as possible. For Rhizoctonia control after transplanting, fungicides such as Cleary's 3336, Terraclor, Medallion, or Heritage should be applied.

Botrytis may attack on the crown and Pythium, Fusarium, or Alternaria on the roots. Fungus gnat larvae readily attack anemone roots and can be controlled with appropriate insecticides. **GG**

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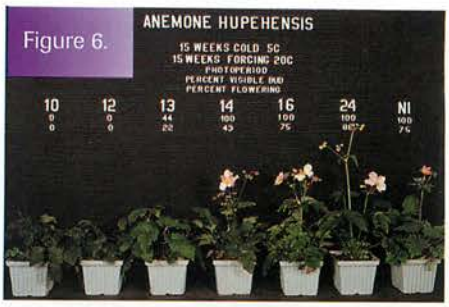


Figure 6. Anemone critical photoperiod experiment showing flowering on cold-treated plants under photoperiods longer than 13 hours.
Figure 7. Lower leaf death caused by petiole breakage from plant expansion.

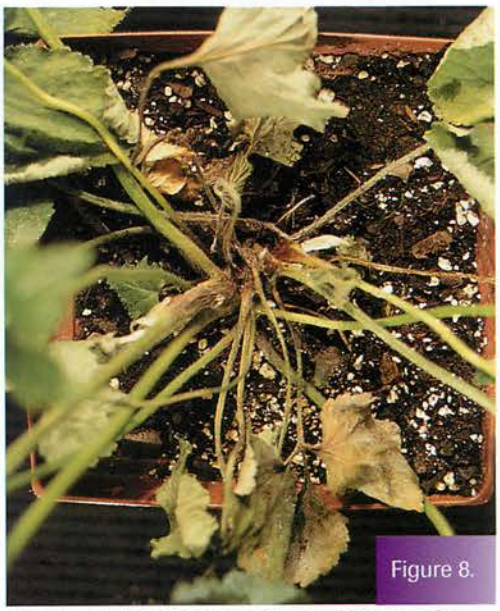


Figure 8. Anemone affected by Rhizoctonia. The plant can be pulled, easily separating the main shoot from the roots.

– Crop By Crop –

FORCING PERENNIALS

Species: *Astilbe*
Common name: False Spirea


Figure 1a.


Figure 1b.

Figure 1. An appealing variety of field-grown astilbe forced in a greenhouse (a). Seed propagated species (*A. chinensis pumila*) also make attractive potted plants (b).

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

THE attractive compound leaves and plume-like inflorescences of astilbe has made it the fifth best-selling herbaceous perennial in the U.S. and Canada. In the landscape, astilbe is a summer-flowering genus hardy to USDA zones 5-8, and prefers partial shade. It is a demanding plant in that it requires moist, well-drained soils, but the reward of a plant in flower is well worth the effort.

Astilbe makes an attractive potted plant and cut flower, with a variety of species having different flowering characteristics from which to choose (Figures 1a and 1b).

There are a multitude of excellent astilbe garden selections, some of which are well suited for potted plant production (DeHertogh, 1996). Perhaps the most common species are *A.* x*arendsii*, *A. chinensis*, and *A. japonica*.

Table 1 provides a list of many of the species and cultivars that we have studied, as well as their flower color and natural plant height in containers. Many other cultivars also exist.

In general, flower color and timing of vegetatively propagated cultivars are consistent within a population. For seed-propagated material, flower color within a species can vary from white to blush pink to deep magenta, and flowering time is longer and more variable. However, some dwarf seed-propagated species flower uniformly and are great candidates for flowering potted plant production.

1. Propagation

Most astilbe are propagated by division, but some are by seed. Most bare-root plant material is grown in The Netherlands and shipped to wholesale growers and distributers in North America. For seed propagation, sow seeds in the light at 63°-70°F (17°-21°C). Germination will occur in 7-14 days. Plugs (with 3-4 leaves) are ready for shipping or transplanting into larger containers in 8-10 weeks.

2. Plant Size

Many cultivars are available as bare-root, field-grown material (Figure 2a), which generally is mature and capable of flowering. The larger field-grown divisions (left) are suitable for 6-inch or gallon production; lower-grade divisions (right) are best reserved for 5-inch pots.

Some seed-propagated astilbe (Figure 2b) have a juvenile period in which they are incapable of flowering. To ensure uniform and complete flowering, we recommend that seed-propagated species have at least 5 (for *A. chinensis, A. chinensis pumila,* and *A. taquetii*) or 7 (for *A. xarendsii*) leaves before cold treatment. Five-inch pots are an appropriate final container size for these plants.

3. Cold Treatment

In nearly all instances, astilbe must undergo a cold treatment for flowering. The duration of cold required for complete, rapid, and uniform flowering varies by cultivar and starting material, but in general, bare-root plants require at least 10-12 weeks of cold at ≤41°F (5°C) (DeHertogh, 1996). Producers commonly store bare-root crowns below freezing. This duration of cold storage can be applied toward the cold requirement, providing that crowns are not exposed to warm temperatures for more than a few days.

For seed-propagated astilbe, we recommend cooling plugs for 15 weeks at 41°F (5°C) so that all plants in a population flower with a high inflorescence count. Shorter durations (9 or 12 weeks) induce flowering, but flowering percentage and inflorescence number are lower. Cool plugs in a cooler (9-hour photoperiods with approximately 25-50 foot-candles of light) or cold greenhouse (with natural short photoperiods). Reduce watering frequency since crowns go dormant and foliage dies back.

Figure 2a.

Figure 2b.

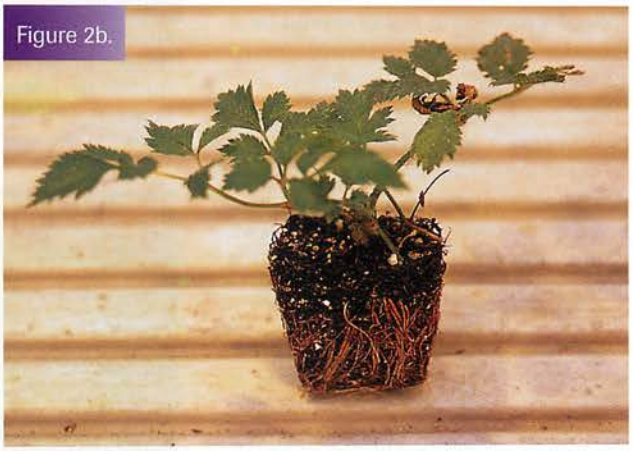


Figure 2. Starting material of astilbe: field-grown, bare-root divisions (a) or plugs from seed (b).

4. Photoperiod

Astilbe are sensitive to photoperiod prior to cold treat-

Table 1. ***Flowering characteristics of various Astilbe spp. forced in containers at 68°F (20°C).***

Species	*A. xarendsii*				*A. chinensis*	*A. chinensis*	*A. japonica*		*A. thunbergii*
Cultivar	Bridal Veil	Cattleya	Fanal	Spinell	Superba	*pumila*	Deutschland	Peach Blossom	Ostrich Plume
Flower color									
Plant height	16 inches (41cm)	21 inches (54 cm)	16 inches (40 cm)	17 inches (44 cm)	19 inches (49 cm)	10 inches (25 cm)	11 inches (27 cm)	15 inches (38 cm)	19 inches (48 cm)
Weeks to first flower	7	7	6	7	8.5	11	5	6	7

ment. Under short days (less than 16 hours of light), growth ceases and plants go dormant within a few weeks. Thus, to bulk seed-propagated plants, long days should be provided by extending the natural photoperiod to 16 hours, or by providing a 4-hour night interruption (NI) (for example, 10 p.m. to 2 a.m.).

Seed-propagated plants should be forced under photoperiods of at least 12 hours following cold treatment (Figure 3). Longer photoperiods (16 hours or with NI) accelerate flowering by up to a week. Under natural short day photoperiods, light with a minimum of 10 footcandles at plant height. Plants grown under continual light (24 hours per day) flower nonuniformly and are very tall.

Daylength has no horticultural effect on flowering of bare root plants (Figure 4), except that plants can be taller under long days than short ones. Thus, following cold treatment, provide field-grown plants with natural photoperiods during forcing.

5. Media, Fertilization, And Irrigation

Astilbe prefers a moist, well-drained medium with a slightly acidic pH (5.8-6.2). A constant fertilization regimen of 100-150 ppm N, 10-20 ppm P, and 100-150 ppm K (for example, 20-10-20) is sufficient for growth and flowering.

Astilbe does not tolerate water stress. Plants require relatively frequent irrigation, especially under high-light levels. If plants dry out, their foliage irreversibly turns brown and crispy, which makes plants unattractive and perhaps unsalable.

6. Lighting And Spacing

Astilbe prefers moderate light levels, and plants should be shaded during periods of high light intensity. Supplemental lighting is generally not necessary. Plants can be placed pot-to-pot until growth reaches beyond the pot; thereafter, space plants to prevent elongation and thin growth.

7. Plant Height Control

Naturally short, compact species and cultivars (*A. chinensis pumila* and *A. japonica* 'Deutschland' and 'Peach Blossom') are well suited for potted plant production since height control is not necessary.

For taller cultivars, DeHertogh (1989) recommends applying B-Nine as a foliar spray (two 5000 ppm applications 1 week apart) soon after inflorescences begin to elongate. The timing of the application is critical. In our trials, all five tested growth retardants were ineffective at limiting plant height since they were applied prior to inflorescence elongation.

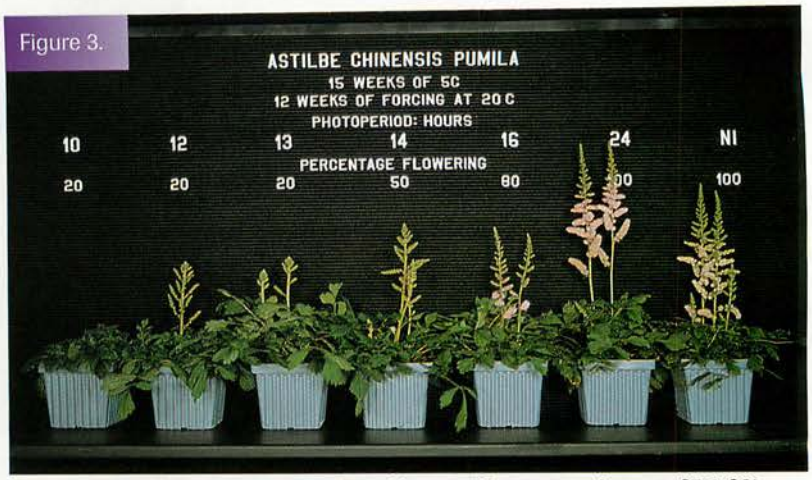


Figure 3. *Astilbe chinensis pumila* cold treated for 15 weeks at 41°F (5°C) flowers under photoperiods of at least 12 hours or with a 4-hour night interruption (NI). Most rapid flowering occurs under photoperiods of at least 16 hours or with NI. Flowering percentage represents the proportion of plants in flower at the time the photograph was taken.

Figure 4. Cold treated field-grown, bare-root astilbe flower regardless of photoperiod. Short days (SD) equal 9-hour days. Long days (LD) equal 9-hour days with a 4-hour night interruption.

8. Temperatures And Crop Scheduling

Seed-propagated plants take approximately 11 weeks to flower at 68°F (20°C) and 14 weeks at 63°F (17°C) after 15 weeks of cold (Table 2). Warmer temperatures hastened flowering by no more than 1 week, and plants forced above 73°F (23°C) displayed heat stress symptoms, such as necrotic leaf margins and even plant death (Figure 5). Inflorescence number is greatest and plants are tallest at cooler temperatures (63°-68°F or 17°-20°C). During forcing, plants develop approximately seven nodes below the first inflorescence.

Time to flower for field-grown plants varies by cultivar, ranging from 5 to $8^1/_2$ weeks at 68°F (20°C) (Table 1). Regardless of cultivar, plants take 26 -34 days from visible

Table 2. **Astilbe chinensis pumila Production Schedule**

Growing time	Cultural practice	Temperature	Photoperiod
1-2 weeks	Sow seeds Germination	63°-70°F (17°-21°C)	Natural daylength
8-10 weeks	Grow on until ≥ 5 leaves	63°-68°F (17°-20°C)	≥ 16 hours or 4-hour night interruption
-OR- *Plant plugs with ≥ 5 leaves*			
15 weeks	Cold treatment	35°-45°F (1°-7°C)	Natural daylength or 9 hours of light in the cooler
Begin forcing			***≥ 16 hours or 4-hour night interruption***
↓ ↓ ↓ ↓ ↓	↓ ↓ 68°F (20°C) Flower in 77 days (11 weeks)	↓ 73°F (23°C) Flower in 74 days (10.5 weeks)	***Visible bud to flower*** 63°F (17°C) - 43 days 68°F (20°C) - 31 days 73°F (23°C) - 29 days
63°F (17°C) Flower in 98 days (14 weeks)			

inflorescence to first flower.

9. Disease And Insect Pests

Plants are susceptible to Pythium and Botrytis because plants need to be kept moist at all times. To reduce disease incidence, avoid watering after mid-afternoon. Removing dead leaves and drenching plants with a fungicide at planting is also recommended. We have not observed any particular insect problems with astilbe.

10. Postharvest Concerns

The pink- and red-flowering cultivars have a long postharvest life (2 or 3 weeks), but the white-flowering cultivars are shorter lived (1 week), and are perhaps best sold just prior to first flowering. Care should be taken so that plants do not dry out, even for short periods of time. **GG**

References:

DeHertogh, A.A. 1996. *Holland Bulb Forcer's Guide*, 5th ed. Intl. Flower Bulb Centre, Hillegom, The Netherlands.

DeHertogh, A.A. 1989. *Holland Bulb Forcer's Guide*, 4th ed. Intl. Flower Bulb Centre, Hillegom, The Netherlands.

Figure 5.

Figure 5. Flowering of *A. chinensis pumila* takes approximately 14 weeks at 63°F (17°C), 11 weeks at 68°F (20°C), and 10 1/2 weeks at 73°F (23°C). At warmer temperatures, inflorescence count decreased and plants became stressed, as indicated by the necrotic leaf margins.

Formula For Success: Astilbe

1. For vegetative growth, provide noncooled plants with photoperiods ≥16 hours, or use a 4-hour night interruption.

2. Provide field-grown, bare-root plants with ≥10 weeks of cold. For seed propagated astilbe (*A. chinensis pumila*), provide plants that have ≥ five leaves with 15 weeks of cold followed by photoperiods of ≥12 hours.

3. Force plants at ~68°F (20°C); avoid temperatures above 73°F (23°C).

4. Never allow plants to dry out and shade plants under high light intensities.

About the authors: Erik S. Runkle 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.

They would like to thank generous industry supporters and research contributor Alison Frane.

– Crop By Crop –

FORCING PERENNIALS

Species: *Campanula carpatica* 'Blue Clips'
Common Name: Carpathian Harebell

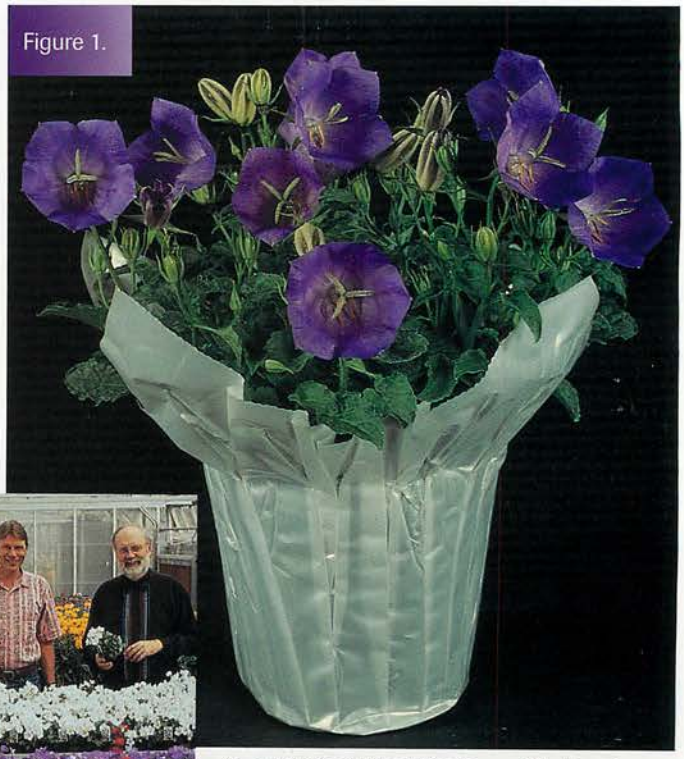
by ***CATHERINE WHITMAN, ROYAL D. HEINS, ARTHUR CAMERON,*** *and* ***WILL CARLSON***

THERE are more than 300 species within the Campanula genus, many of which have been popular garden plants for hundreds of years. *Campanula carpatica* is native to the Carpathian mountains of Eastern Europe and is also known as "Carpathian harebell." Recommendations in this article apply only to this plant and may not be appropriate for other species of Campanula.

C. carpatica is hardy from USDA zones 3 to 8 and has a long flowering season. The plant grows as a compact mound 9-12 inches in height, which is ideal for rock gardens or edging a flower bed. The blue or white flowers are bell-shaped, face upwards, and are held above the foliage (Figure 1). This attractive, showy plant is used extensively in perennial gardens in the U.S. and in Europe.

C. carpatica is an important pot crop in Northern Europe and could easily be adapted to that use in North America. It is an attractive potted flowering plant, as well as a long-lived addition to the home garden. *C. carpatica* responds strongly to photoperiod, so growers can control plant development and schedule flowering quite predictably.

Figure 1.



***C. carpatica* 'Blue Clips' in a 4-inch pot – a real charmer.**

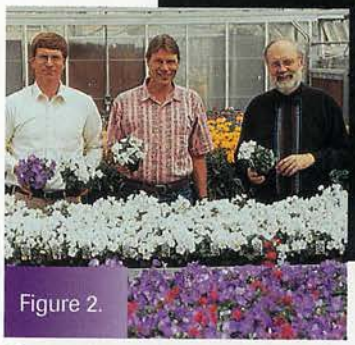


Figure 2.

Successful production of *C. carpatica* 'Blue Clips' and 'White Clips' at Michigan State University. Left to right: Drs. Royal Heins, Art Cameron, and Will Carlson.

Cultivars

The most common seed-propagated cultivars in North America are 'Blue Clips,' with medium lavender/blue flowers, and 'White Clips' with clear, white flowers (Figure 2). Recent introductions include 'Deep Blue Clips,' which has flowers of darker lavender/blue, and the 'Uniform' series. 'Karl Foerster' is a clone with lilac-blue flowers that is grown extensively in Europe. Suggested production information in this article was primarily tested on 'Blue Clips,' and some experiments included 'White Clips.' While we expect that other cultivars of *C. carpatica* will respond similarly, our recommendations may not be appropriate for all cultivars.

Flower Induction Requirements

Daylength is the main factor controlling flowering in *C. carpatica* 'Blue Clips' and 'White Clips.' This species is an obligate long-day plant – it will not flower under short days.

1. PLANT SIZE

Small seedlings of 'Blue Clips' can be induced to flower,

and we have even observed flowering on 9- to 11-leaf plants in plug trays when long daylengths were provided during germination. However, to produce an attractive flowering potted plant, plants need a period of vegetative growth to gain size or "bulk up" before flowering is induced.

At all stages prior to reproductive forcing, 'Blue Clips' should be grown under daylengths shorter than 13 hours to avoid premature floral initiation and to promote lateral branching. Natural daylengths in late winter and early spring are ideal for this stage. After April 1, natural daylengths will be too long for bulking, so if bulking is needed, plants should be placed under blackcloth until reproductive forcing begins. Bulking will result in more attractive finished plants with greater number of flowers at sale (Figures 3 and 4).

These *C. carpatica* plants were placed under long-days (LD) immediately after transplant from 128-cell plug trays, when they had approximately 8-10 leaves. LD were provided with a 4-hour night interruption. Photo was taken after 8 weeks of LD.

***C. carpatica* plants were allowed to bulk, after transplant from 128-cell plug trays, under a 9-hour photoperiod for 3 weeks before LD treatments began. Plants had approximately 15-17 leaves at the start of LD. Photo was taken after 7 weeks of LD.**

2. COLD TREATMENT

Cold temperatures are not required for flowering of 'Blue Clips.' Exposure to cold does not significantly hasten flowering and has little effect on plant appearance. However, cold is not detrimental either, and plants can readily be held or overwintered in a cooler or cold greenhouse at 35°-45°F (2°-7°C) or colder if necessary.

3. PHOTOPERIOD

Under photoperiods of 12 hours or less, 'Blue Clips' remains vegetative and forms a compact rosette of leaves. Flower induction occurs when the photoperiod exceeds 14 hours and is hastened under 16-hour photoperiods or a 4-hour night break (Figure 5). After flower initiation has occurred and buds are visible, flowering will occur even if the plants are subsequently placed under short days. Under short days, some of the elongation associated with long-day (LD) bolting will decrease, hence plants will be shorter.

LD treatments can begin any time after the plants have at least 15 leaves and should continue at least until flower buds are visible. LD can be provided either by extending the daylength to 16 hours or by night-break lighting for 4 hours from 10 p.m. to 2 a.m. Flowering will be slower if night breaks are less than 4 hours (Figure 6).

Cyclic Lighting

We have also tested two cyclic lighting programs, lighting plants for 10% or 20% of the 4-hour night break (Figure 6). The 10% lighting program (lights on for 6 minutes, off for 54 minutes) was not effective for flower induction. Under the 20% lighting program (lights on for 6 minutes, off for 24 minutes), all plants eventually bloomed but flowering was delayed

Critical photoperiod for flowering of *C. carpatica*. All plants under 16-hour photoperiods or 4-hour night-interruption treatments eventually flowered. Less than 60% flowered under the 14-hour photoperiod, and none flowered under photoperiods shorter than 14 hours. *Photo courtesy of Erik Runkle.*

Effectiveness of different night-interruption treatments for flowering of *C. carpatica*. Flowering was slower under night breaks of less than 4 hours. We also tested two cyclic lighting programs, lighting plants for 10% or 20% of the 4-hour night break. The 10% lighting program (lights on for 6 minutes, off for 54 minutes) was not effective for flower induction. Under the 20% lighting program (lights on for 6 minutes, off for 24 minutes), all plants eventually bloomed, but flowering was delayed and not uniform. *Photo courtesy of Erik Runkle.*

and not uniform. For rapid and uniform flowering, night breaks should be 4 hours long, and the lights should be on the entire 4 hours.

Light Source

Incandescent, high-pressure sodium, cool-white fluorescent, or metal halide lamps are effective, but incandescent lights generally cause more stem elongation than the other light sources. Provide a minimum light intensity of 5-10 footcandles. When using incandescent lamps, about 1.5 watts of lamp wattage per square foot of growing space is required. 'Blue Clips' are very sensitive to light, and a light intensity of 0.5 footcandle will induce some flowering. Growers should be aware that light from adjacent greenhouses may affect development of 'Blue Clips' and could inadvertently result in flower induction when vegetative growth is desired.

4. PROPAGATION

C. carpatica can be propagated easily by cuttings or by seed. In North America, most plants are started from seed. Some seedling variation will be present, but available cultivars are quite uniform. Light is required for germination, so the small seeds should not be covered. Maintain medium temperatures at 68°-72°F (20°-22°C). Seedlings will emerge in 14-20 days. After germination, the photoperiod should be maintained at less than 14 hours to maintain vegetative growth. Established seedlings are readily available from plug producers. In our experience, seedlings from 128-cell trays have 8-12 leaves, and those from 50-cell trays have 12-17 leaves.

5. MEDIA AND FERTILIZATION

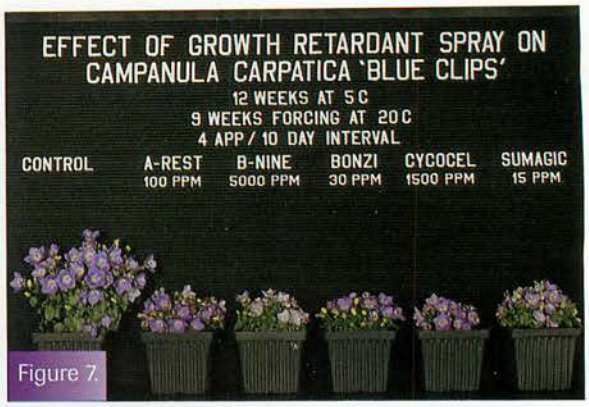
Use of a well-drained medium is especially important. The pH should be maintained around 6.0. Campanula requires moderate levels of fertility, and constant fertilization at 100-150 ppm N, 10-20 ppm P, and 100-150 ppm K20 is adequate (for example, 20-10-20).

6. LIGHTING AND SPACING

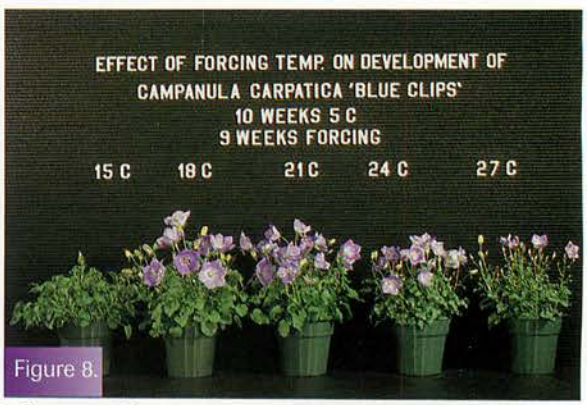
Provide full natural light intensity during late spring forcing. Supplemental lighting with 500 footcandles of light from high-pressure sodium lamps has greatly improved plant quality during winter and early spring forcing in Michigan.

7. IRRIGATION

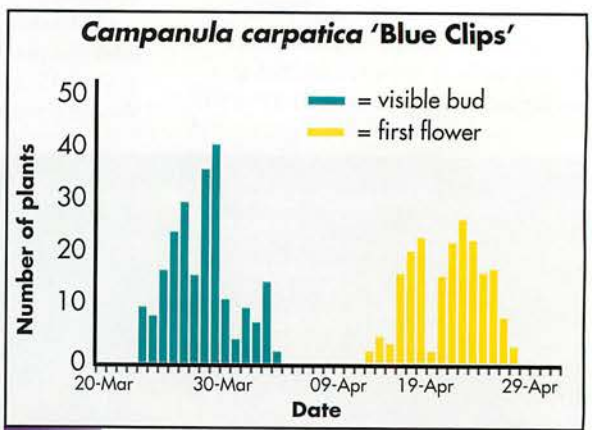
Keep plants evenly moist, avoiding waterlogging or drought. Repeated drought will delay flowering, and reduce plant quality.



Response of *C. carpatica* to common growth retardants applied frequently and at high rates. Applications began 10 days after LD treatments began. This experiment was intended only to determine which compounds would be effective, not to determine recommended rates. *Photo courtesy of Cheryl Hamaker.*



Influence of forcing temperature on flowering in *C. carpatica*. Plants flowered more quickly under warmer temperatures, but note the marked reduction in flower size with increasing forcing temperature. Average daily temperature did not affect plant height.



Distribution of plants reaching visible bud and opening of first flower in a 194-plant population we forced to bloom at 65°F (18°C).

8. PLANT HEIGHT CONTROL

'Blue Clips' is naturally quite compact and generally forms a well-proportioned potted plant. If needed, several cultural techniques can be used to control plant height. Plants grown under positive DIF (mathematical DIF-ference between day and night temperatures) conditions will be taller than those grown under 0 DIF or negative DIF. A 2-hour temperature drop at sunrise also reduced final plant height in experiments at Michigan State University (MSU). Average daily temperature does not affect plant height.

The type of supplemental lighting used to provide LD will influence plant height. Incandescent lights cause more elonga-

TABLE 1. *Campanula carpatica* ' Blue Clips' Production Schedule

Growing Time	Cultural Practice	Temperature	Photoperiod
2-3 weeks	Sow seeds ↓ Germination OR purchase plugs	68°-72°F (20°-22°C)	<13 hours of light
9-11 weeks	Grow on until at least 15 leaves have formed ↓	64°-68°F (18°-20°C)	<13 hours of light
Hold at 35°-45°F (1°-7°C) if needed. (Plants do not require cold to flower.)			
Begin forcing			16 hours of light or 4-hour night interruption
↓ ↓ ↓ 61°F(16°C) 10-11 weeks flower	↓ ↓ 66°F(19°C) 8-9 weeks flower	↓ 70°F (21°C) 7-8 weeks flower	**Visible Bud to Flower** 61°F (16°C) - 26 days 66°F (19°C) - 22 days 70°F (21°C) - 20 days

tion than high-pressure sodium, metal halide, or cool-white fluorescent due to the higher proportion of far-red light emitted by incandescent lamps. In our experiments, 'Blue Clips' treated with incandescent lamps were 1-2 inches taller than those under any other light source.

Growth regulators can also be used to control height. Our research shows that A-rest, B-Nine, Bonzi, Cycocel, and Sumagic are all effective (Figure 7).

9. TEMPERATURES AND CROP SCHEDULING

The time to flower after beginning LD depends on forcing temperature: about 10-11 weeks at 60°F (15°C), 8-9 weeks at 65°F (18°C), or 7-8 weeks at 70°F (21°C). During forcing, we suggest temperatures of 60°-68°F (16°-20°C) since flower size is larger at cooler temperatures (Figure 8).

'Blue Clips' plants are available in several plug sizes and as field-grown divisions. Plants from 128-cell plug trays are appropriate for 4-inch pots. To fill out 6-inch or gallon pots use several small plugs or plants from 50-cell trays or larger.

'Blue Clips' are generally quite uniform but do show some variability in time to visible bud and flower within a population (Figure 9). In this example of 194 plants, date of first flower occurred over a 10-day period. Variability in a population of 'White Clips' was similar. Plants are attractive for a period of time as subsequent flowers open.

Formula For Success: 'Blueclips'

1. Photoperiod is the key! Daylengths should be less than 13 hours until you're ready to begin forcing them to flower, then provide photoperiods of 16 hours, or a 4-hour night interruption.

2. Grow plants under daylengths less than 13 hours or until they have 15 or more leaves. This bulking time will increase final flower number.

3. Force under cool conditions, 68˚F (20˚C) or less. Plants forced at 61˚F (16˚C) at MSU were more attractive, in terms of size and number of flowers, than those at any higher temperatures.

4. Plants from 128-cell plug trays are appropriate for 4-inch pots. Use plants from 50-cell trays or larger to fill out 6-inch or gallon pots.

5. Cold treatments are not required for flowering and have little effect on time to flower or plant appearance. Plants are quite hardy and can readily be held or overwintered in coolers or a cool greenhouse.

10. DISEASE AND INSECT PESTS

'Blue Clips' is susceptible to damping-off root rot caused by Pythium or Rhizoctonia. Use of a well-drained medium will help to reduce these problems. Leaves may become infected by *Botrytis cinerea*, so it is helpful to keep the foliage as dry as possible.

Few insects are attracted to 'Blue Clips,' but spider mites may become a problem. We have noticed that pesticide applications caused some discoloration of open flowers, so avoid spraying blooming plants if possible.

11. POSTHARVEST CONCERNS

Conditions in the retail setting or the consumer's home are very different from those of the greenhouse. Water may not be provided regularly, and salt damage to the roots is a potential problem if the medium is nutrient-rich and allowed to dry out. For maximum shelflife, a reduction in fertilization near the end of the crop is recommended. Two or 3 weeks before harvest, begin irrigating with clear water or use reduced levels of fertilizer – especially nitrogen.

Flower longevity is correlated with ethylene production. In Europe, a spray of 6 ppm of silver in the form of silver thiosulfate is commonly applied shortly before harvest to maximize postharvest life. **GG**

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– Crop By Crop –

FORCING PERENNIALS

Species: *Campanula* 'Birch Hybrid'
Common name: Campanula/Bellflower

Figure 1.

Figure 1. Campanula 'Birch Hybrid' makes an outstanding flowering potted perennial. This campanula is an outstanding selection because of its ample show of flowers and long bloom time. *Photo courtesy of Leslie Finical.*

by ***LESLIE FINICAL, ALISON FRANE, ARTHUR CAMERON, ROYAL D. HEINS,*** *and* ***WILL CARLSON***

Almost spectacular addition to any garden, campanulas have much to offer, with showy flowers and a long bloom time. The Campanulaceae family includes more than 600 species that are annual, biennial, or perennial in nature. Native to the Northern hemisphere and especially concentrated in the Mediterranean sea area, campanulas are tough, versatile, and will grow in climates ranging from USDA zones 4 to 9. Plant performance is best where summers are cool.

Popular garden *Campanula* species include *C. carpatica* 'Carpathian harebell,' *C. glomerata* 'Clustered Bellflower,' *C. medium* 'Canterbury Bells,' and *C. persicifolia* 'Peach-leaved Bellflower.' These species produce flowers atop stalks ranging from 6 inches to 4 feet tall.

There are several short-spreading species on the market, including *C. isophylla* 'White Italian bellflower,' *C. poscharskyana* 'Poscharsy Bellflower,' and *C. portenschlagiana*. The flowers are showy, bell-like, and will vary in size, form, and color. The five-lobed corollas come in a range of blue hues: purple to blue-white and also pink.

Campanula 'Birch Hybrid' (Figure 1) is an outstanding selection that is a cross between *C. portenschlagiana* and *C. poscharskyana*. *Campanula* 'Birch Hybrid' was introduced by Ingwerson and was named after the nursery where it was propagated – Birch Farm. There is a species named *C. betulifolia* that is sometimes confused with *Campanula* 'Birch Hybrid.' Although the nomenclature is somewhat misleading, these are different species.

Campanula 'Birch Hybrid' is a vigorous, evergreen perennial with toothed, kidney-shaped basal leaves on

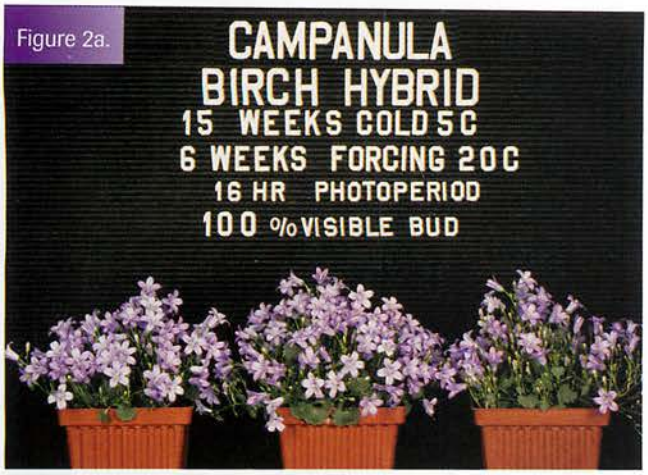

Figure 2a. Influence of cooling on different-sized starting material of *Campanula* 'Birch Hybrid.' Here, 128-cell plugs were given a 15-week cold treatment and then grown under 16-hour days with high-pressure sodium lamps. *Photo courtesy of Leslie Finical.*

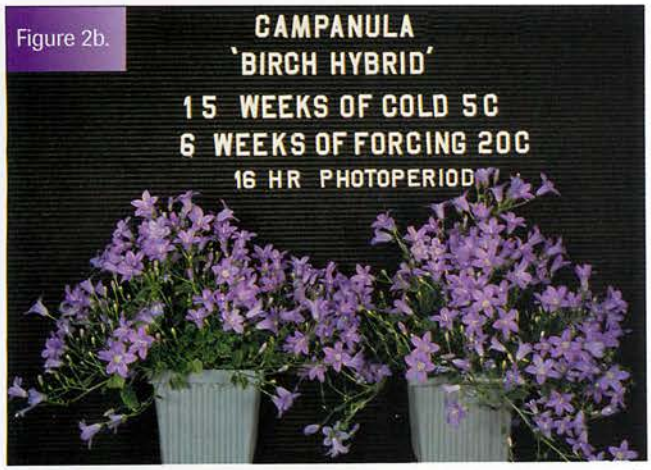

Figure 2b. Influence of cooling on different-sized starting material of *Campanula* 'Birch Hybrid.' 72-cell plugs were given a 15-week cold treatment and then grown under 16-hour days with high-pressure sodium lamps. *Photo courtesy of Leslie Finical.*

long petioles. The branching stems bear numerous open star-shaped flowers that are deep violet in color. At its best, flowers will cover the entire plant in a 5-inch pot. New flowers continue to open June through September. Plant height and spread are 6 inches (15 centimeters) and 12 inches (30 centimeters), respectively. *Campanula* 'Birch Hybrid' is a true winner and should be included in any perennial-forcing program.

All the following production information is based on observed responses of *Campanula* 'Birch Hybrid.' Because flowering requirements within campanula vary, other species may not respond in the same manner.

1. Propagation

In the garden, *Campanula* 'Birch Hybrid' is propagated by division in spring or fall. In the greenhouse industry, plants are propagated vegetatively by stem cuttings or division.

Obtaining production quality cuttings from campanula 'Birch Hybrid' is fairly simple. The best photoperiod for cutting production is short days, when photoperiods are less than 12 hours. Plants grown under short days produced many lateral branches with roots. Vegetative cuttings may be taken freely and rooted at 65°-70°F. A small number of plants were propagated as follows: Take 1- to 2-inch cuttings and dip each in a rooting hormone, or separate small- rooted plantlets from stock plant. Plant and grow cuttings in plug trays under short days with mist for 1-2 weeks. The first signs of rooting should appear within 7 days.

2. Plant Size

Juvenility does not seem to be an obstacle in flowering *Campanula* 'Birch Hybrid.' 128-cell plugs, with only 4-5 leaves at transplanting, flowered under 16-hour days with high-pressure sodium lamps (HPS). Time to flower is virtually the same for starting material of different sizes. After 6 weeks of cold at 41°F (5°C), 128-cell plugs flowered in 58 days (68°F forcing temperature), while 72-cell flowered in 56 days.

128-cell plugs had an average flower bud number of 84, while 72-cell plugs averaged 113 flower buds at first flower. 128-cell plugs are appropriate for finishing in 4- to 5-inch pots (Figure 2a). Larger material, such as 72- to 50-cell plugs, may be more appropriate for 1-gallon pots (Figure 2b).

3. Cold Treatment

Campanula 'Birch Hybrid' requires a cold treatment to flower. Without a cold treatment, the plant will remain vegetative under any photoperiod. A 6- to 9-week cold treatment at temperatures between 32°F (0°C) and 45°F (7°C) in a minimally heated greenhouse or lighted cooler is recommended for flower induction.

Increasing the cold treatment from 3 to 6 weeks reduces

Figure 3. Influence of cooling on time to flower and flower number of *Campanula* 'Birch Hybrid.' Plants were given 0-, 3-, and 6-week cold treatments at 41°F (5°C) and then grown in a 68°F (5°C) greenhouse under 16-hour days with high-pressure sodium lamps. *Photo courtesy of Leslie Finical.*

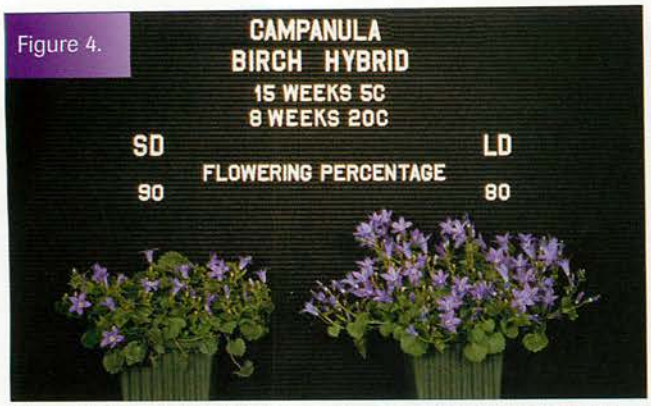

Figure 4. If cooled for 12-15 weeks, campanula 'Birch Hybrid' plants can be forced under both short days (SD) and long days (LD) with incandescent bulbs. *Photo courtesy of Paul Korman.*

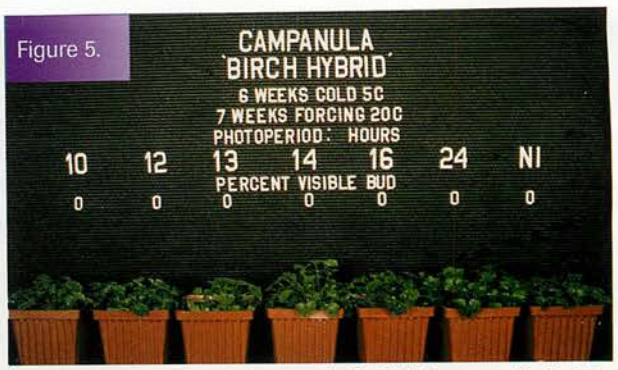

Figure 5. Influence of photoperiodic lighting provided with incandescent bulbs on plants cooled at 41°F (5°C) for 6 weeks. After 7 weeks in a 68°F (5°C) greenhouse, no flower buds were visible under any photoperiod. *Photo courtesy of Leslie Finical.*

time to flower and dramatically increases flower number (Figure 3). Increasing the cold treatment beyond 6 weeks further decreases the time to flower but also decreases the size of the finished plant at flowering.

As the duration of cold increases, the growth habit of 'Birch Hybrid' shifts from prostrate and spreading to upright and elongated. Excessive cooling (15 weeks or more) may cause excessive elongation (Figure 2b).

Plugs tolerate cold exposure well if water stress is prevented. Plugs received 9-hour days with about 50 footcandles of light from cool-white fluorescent lamps in our coolers and were watered once or twice a week.

4. Photoperiod

Campanula 'Birch Hybrid' can be forced under long or short days if it is properly cooled (Figure 4). Technically, 'Birch Hybrid' is considered a facultative long-day plant because it blooms slightly quicker under long days. Under short days, plants are shorter and more compact than plants grown under long days.

5. Lighting And Spacing

Campanula 'Birch Hybrid' grows best in the garden under full sun conditions, but it will tolerate partial shade. Flower number is decreased under low light conditions. Using high-intensity lighting, such as HPS lamps, to provide photoperiodic lighting decreases the time to flower and improves overall plant quality.

Cooled plugs forced under 16-hour day-extension lighting from HPS lamps flowered about 10 days faster and had a higher flower number than those lighted with incandescent bulbs. The decrease in time to flower, though, may be attributed to warmer temperatures caused by high-intensity lighting.

High-intensity lighting also may be necessary to induce flowering of campanula 'Birch Hybrid' plants that have received less than 12 weeks of cold. In one instance, plants were given a 6-week cold treatment and placed under seven different photoperiods. The photoperiods consisted of 9-hour natural days that were extended with incandescent bulbs.

After 10 weeks in the greenhouse, no visible buds were observed under any photoperiod (Figure 5). In contrast, plants given a 15-week cold treatment achieved visible bud in 3-4 weeks under both 9-hour short days and night interruption provided with incandescent lighting (Figure 4).

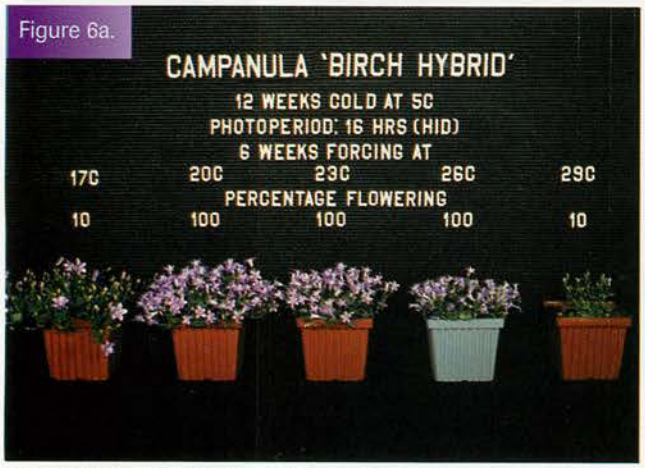

Figure 6a. Influence of forcing temperature on time to flower of *Campanula* 'Birch Hybrid.' Time to flower decreases with increased temperature, but so does quality. *Photo courtesy of Alison Frane.*

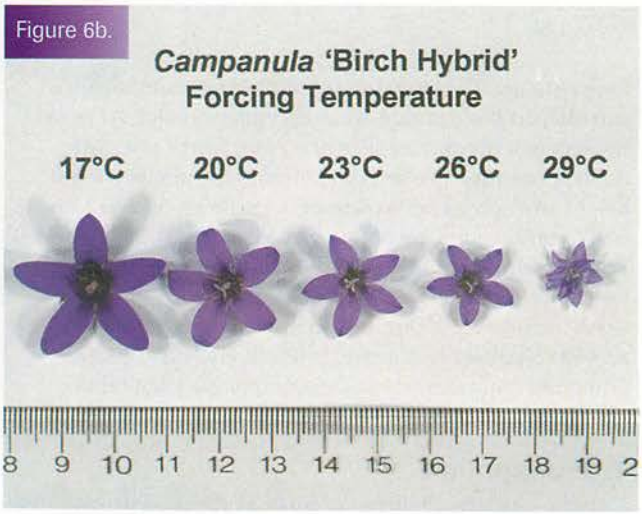

Figure 6b. Influence of forcing temperature on flower size of *Campanula* 'Birch Hybrid.' *Photo courtesy of Alison Frane.*

Table 1. **Campanula 'Birch Hybrid' Production Schedule**

Growing time	Cultural practice	Temperature	Photoperiod
3-4 weeks	Vegetative cuttings Root	72°-76°F (22°-24°C)	Natural short days or photoperiod < 12 hours
4-5 weeks (72-cell plug) Longer for larger	Bulk or pinch to increase vegetative growth	68°-72°F (20°-22°C)	Natural short days or photoperiods < 12 hours
-OR- ***Purchase plugs***			
6-9 weeks	Cold treatment	35°-45°F (2°-7°C)	Natural short days or 9 hours of light in the cooler
Begin forcing ↓ ↓ ↓ ↓ ↓ 64°F (17°C) Flower in 7 weeks	↓ ↓ 68°F (20°C) Flower in 6 weeks	↓ 74°F (23°C) Flower in 5 weeks	***> 16 hours of light with HID or use a 4-hour night interruption with incandescent if plants receive 12-15 weeks of cold at 63°F (17°C)*** ***Number of days from visible bud to flower*** 63°F (17°C) - 26 days 68°F (20°C) - 21 days 74°F (23°C) - 17 days

In one experiment, 128-cell plugs were given a 6-week cold treatment and then grown under 16-hour days with HPS lamps. 100% flowering was observed, and the plants remained under these conditions for 15 weeks. The plants were cut back to the base while still flowering, and half the plants were moved to 9-hour short days. The plants remaining under 16-hour days grew back and resumed flowering, while the plants moved to short days became vegetative. A longer cold treatment may be necessary for plants to resume flowering under short days.

Because the plants are compact, spacing can be fairly close. Spacing 1-2 inches between pots should be sufficient and help minimize the occurrence of disease and stretching.

6. Media, Fertilization, And Irrigation

Generally, campanulas are not picky about soil. Most thrive in chalky soil but will tolerate acid soils. Most are lime-tolerant or have a preference for lime. 'Birch Hybrid' will grow well in any well-drained media.

Plants can tolerate drought and should not be allowed to sit in excess water. The soil pH should range from 6.0 to 7.0. A constant feed of 150-200 ppm 20-10-20 fertilizer is adequate for good growth.

7. Plant Height Control

Campanula 'Birch Hybrid' is a small compact plant that requires no height control.

8. Temperatures And Crop Scheduling

Under long-day conditions, average daily temperature is the primary factor influencing flower development. Increasing temperature decreases time to flower. Although increasing the temperature to speed up the crop may seem desirable, delayed flowering and diminished plant quality may result when a crop is grown too warm.

The time to flower of 'Birch Hybrid' after beginning long days depends on forcing temperature: about 7 weeks at 64°F (17°C), 6 weeks at 68°F (20°C), or 5 weeks at 74°F (23°C). Plants will flower faster at the warmer temperatures up to 78°F (26°C) but will experience heat delay if flowering at temperatures above 78°F (26°C) (Figure 6a). During forcing, try temperatures of 64°-74°F because plant and flower size are larger at cooler temperatures (Figure 6b).

9. Disease And Insect Pests

No disease or insect pests were observed on campanula 'Birch Hybrid' during the course of this research.

10. Postharvest Concerns

Campanula 'Birch Hybrid' will hold the initial flush of flowers for about 4 weeks, after which new flowers will continue to emerge. Because flowers are small, their immediate removal upon senescence is not necessary.

Because plants are fairly drought-tolerant and sturdy, their overall appearance will remain good for quite some time. Cutting them all the way back to the base will result in a quick new flush of vegetative growth, but continued flowering may be sparse. **GG**

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– Crop By Crop –

FORCING PERENNIALS

Species: *Coreopsis grandiflora*
Common Name: Tickseed

by ***MEI YUAN, DR. ROYAL D. HEINS, DR. ARTHUR CAMERON,*** *and* ***DR. WILLIAM H. CARLSON***

COREOPSIS GRANDIFLORA belongs to the Asteraceae plant family. The genus includes many annuals and perennials grown for their daisy-like, bright-yellow flowers. *Coreopsis grandiflora* is indigenous from Missouri and Kansas to Florida and New Mexico and is fully hardy from zones 4 to 9. The plant flowers from early summer to late fall and prefers full sun and fertile, well-drained soil. It grows as a rosette plant and bolts before flowering, often reaching a height of 2 feet. It makes a brilliant display in borders and gardens and is excellent as a cut flower. Coreopsis responds strongly to photoperiod, which allows growers to control and schedule flowering quite easily. It has great potential as a flowering potted plant and can be enjoyed in the home as well as in gardens. (Figure 1).

Figure 1.

Cultivars

The most common cultivar is 'Sunray,' which has double gold-yellow flowers about 1-2 inches across. 'Goldfink' is a short-lived, dwarf plant that has 2-inch single yellow flowers with an orange center. 'Sunburst' has semidouble golden yellow flowers. 'Early Sunrise' is purported to be a cross between *C. grandiflora* and *C. lanceolata*. It is a short-lived cultivar and is unique in that it does not have a requirement for cold before flowering. Many other cultivars also exist.

Flower Induction Requirements

Flowering requirements vary among Coreopsis species and even cultivars. Unless stated otherwise, the following suggested production information is based on 'Sunray.' It may not be appropriate for other cultivars and will not be appropriate for other Coreopsis species such as *C. verticillata* 'Moonbeam' or *C. rosea*. In order to flower, *C. grandiflora* 'Sunray' plants must be mature, must have received a cold treatment, and must be exposed to long days.

1. PLANT SIZE

After germination, seedlings are juvenile and will not flower in response to vernalization or photoperiod. 'Sunray' reaches maturity when plants develop about eight nodes (16 visible leaves). Until then, they should be grown under a photoperiod shorter than 13 hours to promote lateral branching. If only part of a population is mature, only part of the plants will flower (Figure 2). Mature plants will develop about eight new nodes (16 leaves) under the flowers

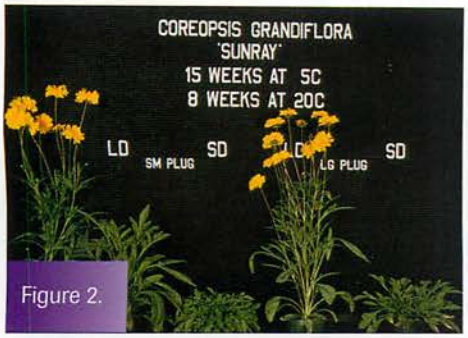


Figure 2.

Only part of a *C. grandiflora* 'Sunray' population may flower if all plants are not mature. Plants from "SM PLUG" were grown in a 128-cell plug sheet; only 50% of the plants flowered. Note the flowering and nonflowering plants after cold and long days on SM PLUG plants. Plants from "LG PLUGS" were grown in a 50-cell plug sheet; all plants flowered under long days (LD) following 10 weeks' cold treatment at 41°F (5°C). *Photo courtesy of Beth Engle.*

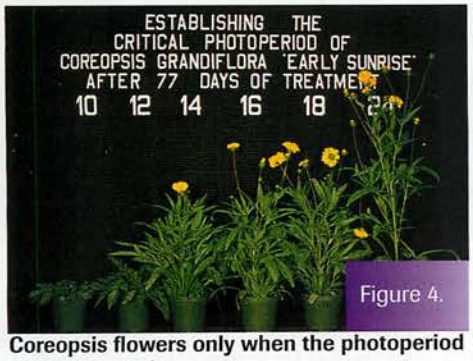


Figure 4.

Coreopsis flowers only when the photoperiod is 14 hours or longer.

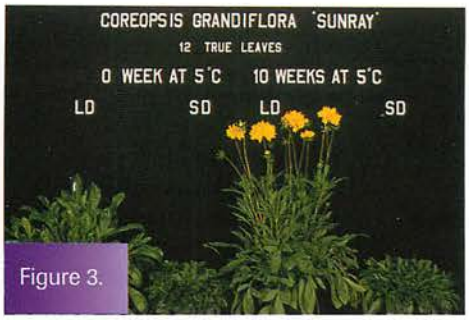


Figure 3.

***C. grandiflora* 'Sunray' plants flower only after receiving a cold treatment and then being forced under long days (LD). Plants on the left did not receive a cold treatment and did not flower, while the two plants on the right received 10 weeks at 41°F (5°C); the plants subsequently forced under LD flowered.**

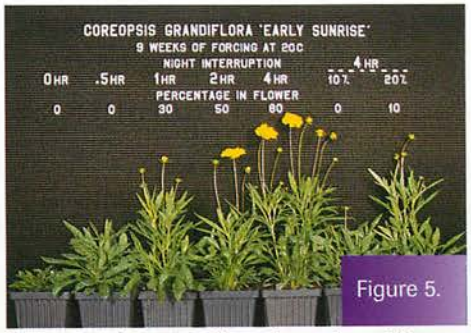


Figure 5.

Fastest and most uniform flowering of *C. grandiflora* under night-interruption lighting occurs when plants are exposed to at least 4 hours of light during the middle of the night. While plants will flower with as little as half an hour of light during the middle of the night or with cyclic lighting (6 minutes on, 54 minutes off for 4 hours), time to flower will be increased with fewer than 4 hours of continuous light. *Photo courtesy of Erik Runkle.*

from forcing to bloom.

2. COLD TREATMENT

A 10-week cold period at about 41°F (5°C) in a cold greenhouse or cooler is recommended for flower induction in 'Sunray' (Figure 3). Extending the cold treatment from 10 to 15 weeks will enhance flowering percentage on marginally mature plants, although the time to flower for flowering plants remains unchanged.

'Early Sunrise' does not have an obligate cold requirement to flower. It does require long days (LD) to flower. We have conflicting experiences about this cultivar's requirement for a period of short days (SD) before exposure to LD. Because we are uncertain at this point, we recommend that 'Early Sunrise' plants be exposed to SD (days shorter than 12 hours) for at least 6 weeks before exposure to LD if precise timing to flower is required.

3. PHOTOPERIOD

Horticulturally, all *C. grandiflora* cultivars, including 'Early Sunrise' and 'Sunray,' are obligate LD plants. Fastest flowering occurs when plants are exposed to LD of 14 hours or more (Figure 4) or are provided night-interruption lighting for 4 hours from 10 p.m. to 2 a.m. (Figure 5). Plants should be exposed to at least 3 weeks of LD. After flowers initiate, their development will continue even if the plants subsequently are placed under SD.

Incandescent, high-pressure sodium, cool-white fluorescent, and metal halide lamps all are effective for night interruption. However, incandescent light may cause more stem elongation than other light sources (Figure 6). The minimum intensity should be 10 footcandles.

4. PROPAGATION

Coreopsis can be propagated by seed or division. Division is used most commonly by the gardener for rejuvenation or control of plant size and is preferably done in the spring. Seed propagation is prevalent for commercial production because it is less expensive. Cold treatment of seed is beneficial but not required for germination. However, darkness is required, which necessitates that seeds be covered with medium or germinated in a dark chamber. Keep the medium at 68°-72°F (20°-22°C) and the humidity high (90%-95%). Seedlings will emerge in about a week.

5. MEDIA AND FERTILIZATION

Coreopsis does not have specific media requirements; plants will grow well in any well-drained evenly moist medium. The pH should be maintained from 5.8-6.4.

Coreopsis prefers low to moderate fertility; constant fertilization at 100-150 ppm N from a balanced fertilizer is adequate. Plants become very lush under high fertility.

6. LIGHTING AND SPACING

Coreopsis thrives in bright light. Supplemental lighting from high-pressure sodium lamps at 400-500 footcandles hastens development and improves quality during winter.

7. IRRIGATION

Plants grow rapidly, develop a large leaf area, and require frequent irrigation. Plants readily wilt as the medium dries under high light conditions, which is especially a problem in small pots. Recovery, however, is rapid after watering without detri-

mental effects, as long as the water stress is not severe.

8. PLANT HEIGHT CONTROL

Coreopsis tends to be too tall when grown in 4- or 6-inch pots. Two methods can be used to control plant height: limited induction photoperiod (LIP) and growth retardants. With LIP, plants are given 3 weeks of LD, then grown to flower under a photoperiod shorter than 14 hours.

Returning plants to SD will delay flowering by up to several days and will reduce flower-bud number compared to continual LD, but plants are shorter. However, once visible, buds develop at the same rate under LD or SD.

Growth regulators also can be used effectively to control plant height. Our research shows that B-Nine and Sumagic are the most effective (Figure 7). Both growth regulators reduce stem elongation under LD conditions but delay flowering in the process. We have observed almost 2 days' delay for every inch in height reduction compared to untreated control plants.

Formula For Success: 'Sunray'

1. Force only plants with 16 or more leaves (8 or more nodes).

2. Provide plants a minimum of 10 weeks' cold at 41°F (5°C) before LD treatment.

3. Force at 60° to 70°F (15°-21°C).

4. Provide plants a minimum of 3 weeks LD after cold treatment. Long days can be provided by natural or extended photoperiods of at least 14 hours or by night interruption from 10 p.m. to 2 a.m. with 10 footcandles of light.

5. To keep plants compact, apply growth retardants when the main stem axis starts to elongate. Expect some flowering delay from growth retardant application.

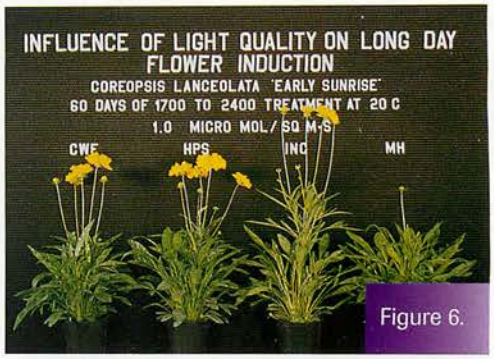
9. TEMPERATURES AND CROP SCHEDULING

Coreopsis grows and develops fast in warm temperatures. After germination, plants should be grown at 70°-75°F (21°-24°C) to shorten the juvenile phase. During forcing to flower, temperatures higher than 70°F (21°C) reduce flower-bud number, so 65°-68°F (18°-20°C) is optimum for fast flowering with high quality.

Once LD begins, time to flower depends on the forcing temperature. Allow about 10-11 weeks at average daily temperatures of 59°F (15°C), 8-9 weeks at 64°F (18°C), or 7-8 weeks at 68°F (20°C) (Table 1 next page).

Plants can be purchased in different size plugs or as field-grown plants (Figures 8, 9, and 10 on next page). Final plant size will depend on the size of the plant at the start of LD.

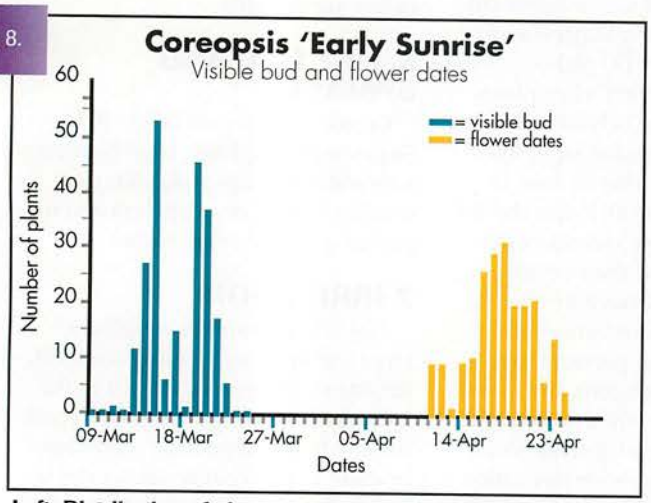
Like many other seed-propagated crops, coreopsis exhibits some variability in time to flower between plants in a population (Figures 11a and 11b). You should consider this type of variability if all plants must be

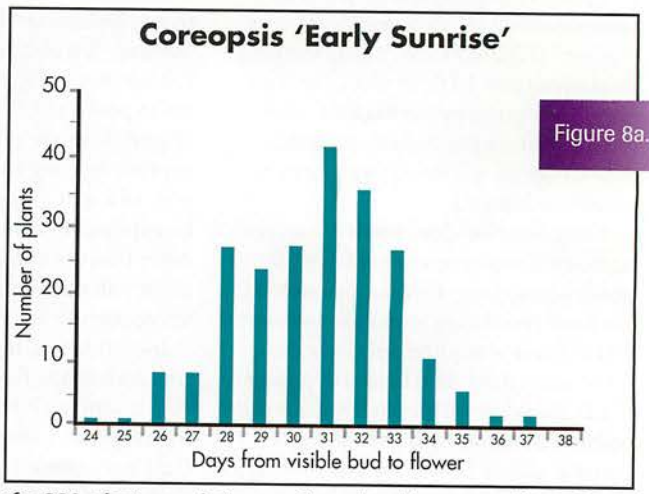


Cool-white flourescent, high-pressure sodium, incandescent, and metal halide lamps all induce flowering of *C. grandiflora*; however, incandescent lamps promote more stem elongation than the other lamps. Note: one micromol/sq. m•s is approximately 5 footcandles. *Photo courtesy of Catherine Whitman.*

Response of *C. grandiflora* to common growth retardants applied frequently and at high rates. B-Nine and Sumagic were both very effective but delayed flowering. Rates are not necessarily those suggested for height control.

Figure 8.





Left: Distribution of plants reaching visible bud (VB) and flower of a 200-plant population we forced to bloom at 65°F (18°C). Right: Distribution in time from VB to flower for 200 *C. grandiflora* 'Early Sunrise' plants growing at 65°F (18°C).

TABLE 1. *Coreopsis grandiflora* 'Sunray' Production Schedule

Growing Time	Cultural Practice	Temperature	Photoperiod
1-2 weeks	Sow seeds ↓ Germination OR purchase plugs	65°-72°F (18°-22°C)	<14 hours of light
8-12 weeks	Grow until at least 16 leaves have formed	72°-76°F (22°-24°C)	<14 hours of light
10-15 weeks (Can be held longer if needed)	Cold treatment ↓	35°-45°F (1°-7°C)	<14 hours of light
	Begin Forcing		
↓ ↓ ↓ ↓ 60°F (15°C) 10-11 weeks flower	↓ ↓ 65°F (18°C) 8-9 weeks flower	↓ 70°F (21°C) 6-7 weeks flower	> 14 hours of light or a 4-hour night interruption. **Visible Bud to Flower** 60°F (15°C) – 35 days 65°F (18°C) – 27 days 70°F (21°C) – 21 days

in flower to be marketed.

Cooled plugs or bare-root plants can be purchased, planted, and directly forced to bloom. For 1-gallon or larger containers, larger plants are required to fill the pot properly. The best options for large containers are 1) using field-grown plants or 2) planting an uncooled plug (size 128 or 50) in late September and early October to allow for bulking.

When plugs are used, plants fill out during the fall and are cooled during the winter in their finish pot. After plants have received adequate cold, they can be forced to bloom under LD. A plant from a 128-cell plug tray is marginal for a 6-inch or larger pot, depending on growing time before LD treatment. Adequate "pot fill" will occur if two or three plugs from 128-cell trays are planted per large pot and then forced to bloom.

10. DISEASE AND INSECT PESTS

Coreopsis does not have many pests but is susceptible to powdery mildew and aphids. Plants are susceptible to tospoviruses such as impatiens necrotic spot virus (INSV), which is spread by thrips and causes black spotting on leaves and petioles.

11. POSTHARVEST CONCERNS

For longer shelf life, plants should be shipped when the first flower opens. Spent flower heads should be removed to keep plants vigorous and prolong blooming. Plants will continue flowering if provided bright light and sufficient water and can be enjoyed for many years as garden plantings. **GG**

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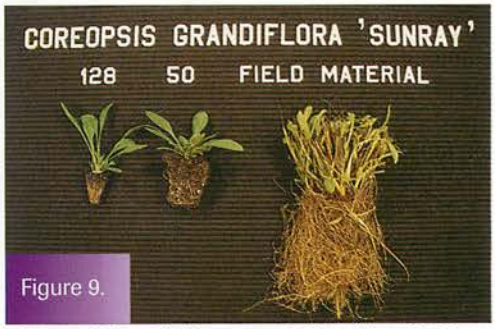

Figure 9.

***C. grandiflora* field-grown, 128-cell, and 50-cell plugs before cold treatment.**

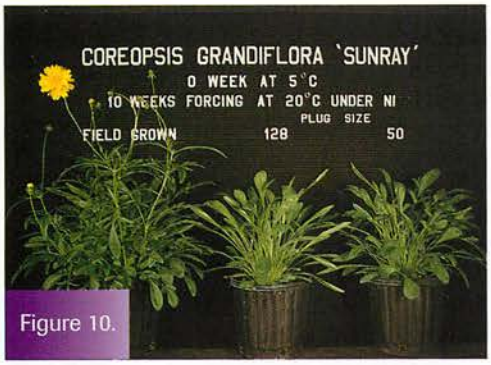

Figure 10.

Left: Field-grown *C. grandiflora* sometimes will flower without a cold treatment because of cooling in the field before digging; however, flowering is delayed and flower count is low. Right: C. grandiflora field-grown, 50-cell, and 128-cell plants following a 10-week cold treatment at 41°F (5°C) and 7 weeks' forcing at 68°F (20°C).

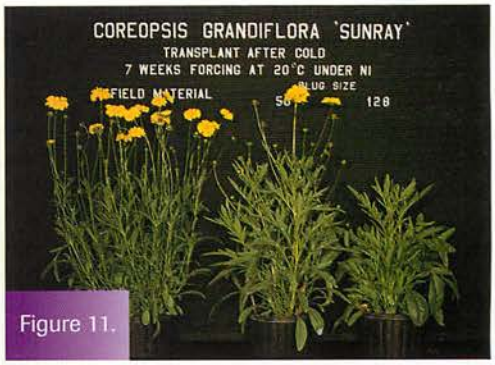

Figure 11.

– Crop By Crop –

FORCING PERENNIALS

Species: *Coreopsis verticillata*
Common Name: Threadleaf Coreopsis

by ***CHERYL K. HAMAKER, ROYAL D. HEINS, ARTHUR CAMERON,*** *and* ***WILL CARLSON***

VOTED Perennial Plant of the Year in 1992 by the Perennial Plant Association, *Coreopsis verticillata* 'Moonbeam' is a showy flowering herbaceous perennial that continues to be popular among consumers. *C. verticillata*, or threadleaf coreopsis, is one of the most drought tolerant of the cultivated Coreopsis species. It has a variety of cultivars that add interesting texture and an extended blooming season to gardens in USDA hardiness zones 3-9.

C. verticillata is a member of a large genus of summer-blooming perennials with yellow daisylike flowers. The Coreopsis species belong to Asteraceae, the daisy family, and are known for their profuse single and double composite flowers. Threadleaf coreopsis is indigenous from Maine to Florida and as far west as Arkansas. *C. verticillata* spreads through growth of rhizomes, or underground stems, which results in expansion of the original crown. Once the initial flush of blooms is finished, plants will reflower continually from new sprouts rising from the crown.

Figure 1.

A field-grown division of Coreopsis 'Moonbeam' will yield an impressive flowering plant, shown here in a 6-inch standard pot.

Cultivars

Threadleaf coreopsis sports dozens of single flowers on soft needle-like leaves that vary in color based on cultivar. 'Golden Showers' is a 2-foot-tall selection with 21/2-inch blooms that are a rich, golden-yellow. 'Zagreb' is a compact version of 'Golden Showers,' reaching only 8-18 inches in height with similar flower color. *C. verticillata* 'Moonbeam' is unique to this species, with pale, lemon-yellow 1-inch blooms atop 1- to 2-foot-tall plants (Figure 1). Selected by Alan Bloom at Bressingham Gardens in England, the blooming season for Coreopsis 'Moonbeam' – from June until frost – is unusually long compared to most perennials.

Flower Induction Requirements

All suggested production information is based on observed responses of *C. verticillata* 'Moonbeam.' Because flowering requirements within Coreopsis vary, other cultivars within this species may not respond the same way.

1. PLANT SIZE

When producing Coreopsis 'Moonbeam' as a flowering potted plant, you must first consider the intended market and the desired final product. Starting material greatly influences the size of the final plant as well as container selection (Figure 2). Starting material, either plugs or divisions, should be able to fill the container with an impressive display of flowers. A comparison between Figures 1 and 2 shows this is more of a concern with plug material.


Figure 2.

Coreopsis 'Moonbeam' is very versatile and can be grown to fit almost any container. It's shown here flowering from a small plug in a 5-inch square pot.

Figure 3.

***Coreopsis verticillata* 'Moonbeam' will flower without a cold treatment. Both plants did not receive cold, but the plant on the left was forced under long days (LD).**

2. COLD TREATMENT

Coreopsis 'Moonbeam' does not require a cold treatment to flower (Figure 3). However, a cold treatment or storage in a cool greenhouse can offer two advantages during forcing. Flowering occurs 1-2 weeks faster after a 10- to 15-week, 41°F (5°C) cold treatment, and final bud count may be increased compared to uncooled plants.

3. PHOTOPERIOD

Because Coreopsis 'Moonbeam' is an obligate long-day (LD) plant, flowering occurs fastest when plants are exposed to a photoperiod in excess of 14 hours or a 4-hour night interruption from 10 p.m. to 2 a.m. (Figure 4). Coreopsis 'Moonbeam' also responds to cyclic lighting as a long-day treatment (Figure 5). Plants should be forced for at least 3 weeks under LD conditions. Flower development will continue even if the plants are then placed under short-day (SD) or natural-day (ND) conditions, but the number of buds will be higher if plants are grown under continual long days.

Cool-white fluorescent, high-pressure sodium, incandescent, and metal halide lamps all have been successful in promoting flowering of Coreopsis 'Moonbeam.' The minimum light intensity for all lamp types should be 10 footcandles.

4. PROPAGATION

Coreopsis 'Moonbeam' is propagated in the garden by division in spring or fall. Plants are divided to rejuvenate old clumps or to increase the number of plantings, control them, or both.

In the commercial industry, Coreopsis 'Moonbeam' has been selected for flower color. It must be vegetatively propagated by stem or root cuttings because plants from seed production are not true to color. In addition, seed production leads to sparse seed set and prevents uniform germination.

Production of quality cuttings for plugs can be difficult. Stock plants of *C. verticillata* 'Moonbeam' grown under photoperiods longer than 13 hours produce abundant cuttings. However, cuttings usually already have been induced to flower under the longer stock-plant photoperiods and the developing flower buds may compete with the rooting process.

Following a cold treatment, it is possible to obtain cuttings from stock plants grown under noninductive conditions. Cuttings taken from stock plants grown under photoperiods shorter than 14 hours root quickly and profusely but fewer cuttings are produced per plant than on stock plants grown under longer photoperiods (Figure 6).

In our experience, cutting production increased two-fold in successive flushes on stock plants grown under photoperiods longer than 13 hours compared to stock plants grown under shorter photoperiods.

Figure 4.

Coreopsis 'Moonbeam' requires a photoperiod longer than 14 hours for fastest flowering. Following a cold treatment, plants will flower under a 12-hour photoperiod, but flowering will be delayed. *Photo courtesy of Erik Runkle.*

However, rooting percentage was less than 50 after 3 weeks.

5. MEDIA AND FERTILIZATION

C. verticillata does not have specific media requirements. Plants will perform well in the greenhouse in any well-drained, evenly moist medium with a pH of 5.8-6.3.

In the garden, plant in average soil with a similar pH. Coreopsis 'Moonbeam' does not require a high fertilizer concentration either in the greenhouse or garden. We suggest a constant fertilization at 100 ppm N from a balanced fertilizer. Under high-nitrogen fertilization, plants become floppy with weak stems.

6. IRRIGATION

While Coreopsis 'Moonbeam' will tolerate dry conditions, best growth

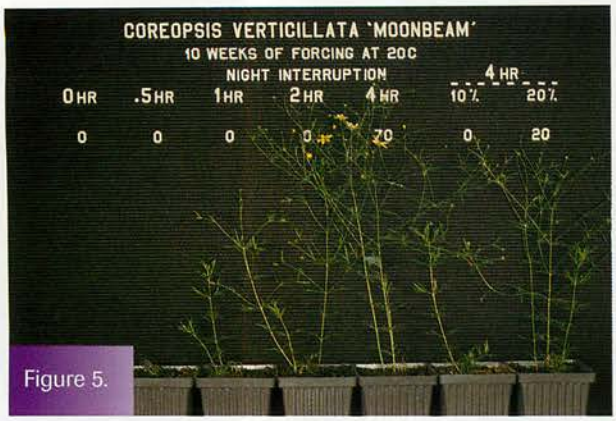

Figure 5.

Coreopsis 'Moonbeam' flowered when plants were grown under night-interruption regimes of at least 4 hours of light. Plants also flowered under either a 2-hour night-interruption treatment or a cyclic lighting treatment (6 minutes on, 24 minutes off for 4 hours) with only a slight delay in flowering. However, plants that were forced under the latter long-day regimes did not flower as uniformly as plants grown under a full 4-hour night interruption. *Photo courtesy of Erik Runkle.*

Figure 6.

Cuttings of *Coreopsis verticillata* 'Moonbeam' were taken from stock plants that received a cold treatment of 15 weeks at 5°C. Rooting percentage and number of roots were higher on cuttings from stock plants grown under photoperiods of 10–13 hours. Cutting production increased from three to 10 cuttings per stock plant when stock plants were grown under a 13-hour photoperiod rather than a 12-hour photoperiod. *Photo courtesy of Paul Koreman.*

occurs when plants are kept evenly moist.

7. LIGHTING AND SPACING

Coreopsis 'Moonbeam' is considered a high-light plant and thrives in full sun. Overall plant quality is best when appropriate lighting and spacing are used. Supplemental lighting from high-intensity discharge lights at 400-500 footcandles is beneficial in greenhouse conditions, especially during dark winter months. To encourage proper growth habit and stem strength, pots should be spaced so light can reach the lower part of the plant.

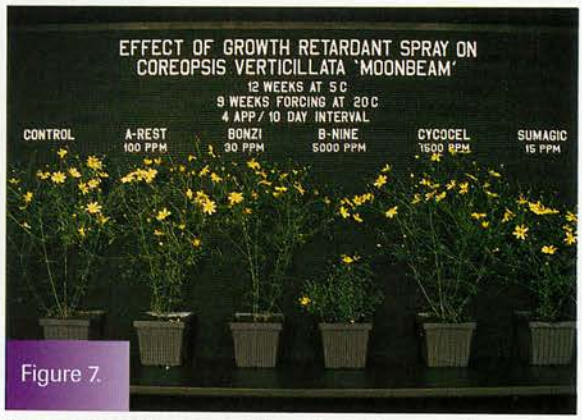

Figure 7.

Response of Coreopsis 'Moonbeam' to growth retardants applied at high rates at 10-day intervals during forcing. Both B-Nine and Sumagic were very effective but B-Nine delayed flowering. Rates used are not necessarily those suggested for height control by commercial growers.

8. PLANT HEIGHT CONTROL

In order for Coreopsis 'Moonbeam' to be successful as a flowering potted plant, its final height must be reduced. Coreopsis 'Moonbeam' responds to at least two methods of height control, growth retardants, and limited induction photoperiod (LIP).

Our research has shown that growth retardants are the easiest and most effective way to control final height of Coreopsis 'Moonbeam.' Both B-Nine and Sumagic effectively reduced stem elongation under LD conditions when used as foliar sprays (Figure 7). However, we observed a 10-day delay in flowering for plants treated with three applications of 5000 ppm B-Nine.

LIP is used to control height through manipulation of photoperiods. Plants are first forced under LD conditions for 3 weeks to induce flower bud formation and then shifted to photoperiods shorter than 14 hours for the remainder of flower development.

An average plant height for Coreopsis 'Moonbeam' is about 18 inches (45 cm). LIP reduces the final height of Coreopsis 'Moonbeam' by 3 inches (8 cm) compared to plants grown under continuous 4-hour night interruption. However, when used as the sole treatment, LIP probably will not provide adequate height control.

9. TEMPERATURES AND CROP SCHEDULING

Forcing a species such as *C. verticillata* 'Moonbeam' requires matching the size of the starting material to the final pot size. Because it is vegetatively propagated, Coreopsis 'Moonbeam' does not have a juvenile stage, and even unrooted cuttings will flower if placed under inductive conditions.

Coreopsis 'Moonbeam' must not be induced to flower before the appropriate vegetative size is obtained. This phenomenon can be influenced by stock plant environment (see propagation section), pinching plugs before forcing, or increasing the vegetative size of the plants in photoperiods short enough to prevent induction but long enough for vegetative development to occur, a process we call bulking.

Generally, field-grown divisions do not require pinching or bulking. However, plug material often benefits from a pinch or a pretreatment designed to increase vegetative size. At planting, decide how you will increase plant size. We suggest that plants be bulked if planted in the fall and pinched if planted in the spring.

TABLE 1. *Coreopsis verticillata* 'Moonbeam' Production Schedule

Growing Time	Cultural Practice	Temperature	Photoperiod
3-4 weeks	Take cuttings ↓ Root	Media temperature 72°-76°F (22°-24°C)	<14 hours of light
4-5 weeks (72-cell plug) Longer for larger plugs	Bulk or pinch to increase vegetative growth of plugs	Air temperature 68°-72°F (20°-22°C) 58°-62°F (14°-17°C) for 1-2 weeks before cold	13-14 hours of light initially 10-12 hours of light for final weeks before cold
– OR – Plant plugs or bare root plants			
10-15 weeks (Can be held longer if needed)	Cold treatment ↓	35°-45°F (2°-7°C)	< 12 hours of light
	Begin Forcing		≥14 hours of light or a 4-hour night interruption
↓ ↓ 65°F (18°C) 9-10 weeks flower	↓ 70°F (21°C) 8-9 weeks flower	↓ 75°F (24°C) 7-8 weeks flower	**Visible Bud to Flower** 65°F (18°C) – 24 days 70°F (21°C) – 20 days 75°F (24°C) – 19 days

Bulking works best on plants that will be overwintered in a low-temperature greenhouse.

Plants are potted in October, then allowed to develop lateral shoots just under the soil line during the fall as daylength decreases. These shoots will develop into flowering shoots when plants are forced under LD in the spring.

The size of flowering plants growing from spring-planted small plugs can be increased by pinching developing shoots. One to three flowering stalks or shoots often develop from smaller plugs when they are planted and placed under LD for forcing.

If these stalks or shoots are pinched when about 2 inches tall and then kept under LD, lateral branches will develop, increasing the number of flowering shoots. While it increases plant size, pinching may make lateral shoots grow horizontally instead of upright.

Time to flower depends on the forcing temperature from the start of long days. As forcing temperatures increase, forcing time decreases. Coreopsis 'Moonbeam' performs best when forced between 65°-75°F (18°-24°C). Allow about 9-10 weeks at average daily temperatures of 65°F (18°C), 8-9 weeks at 70°F (21°C), or 7-8 weeks at 75°F (24°C) (Table 1).

Plants forced at 80°F (27°C) flowered in 6-7 weeks with no adverse effects at the higher temperature. Forcing temperatures below 65°F (18°C) resulted in greatly increased forcing time and a marked reduction in final bud number.

Uncooled or cooled plugs and bare-root plants can be purchased and directly forced into bloom. For small containers – 4- or 5-inch pots – one plug is usually sufficient for final size. In order to fill a 6-inch or 1-gallon container, larger plants are required.

To fill large containers, use field-grown plants or plant an uncooled plug in late September or early October to allow for bulking during the late fall. If small plugs are used as starting material, you may want to plant several in each large container to produce a high quality final product.

Formula For Success: 'Moonbeam'

1. Choose the size of your starting material to match the finish pot size.
2. Provide plants with a 10- to 15-week cold treatment at 41°F (5°C) before LD treatment.
3. Force between 65°F and 75°F (18°-24°C).
4. Provide plants a minimum of 3 weeks' long days after cold treatment. Long days can be provided by natural or extended photoperiods of at least 14 hours or by night interruption from from 10 p.m. to 2 a.m. with a minimum light intensity of 10 footcandles.
5. Apply growth retardants to keep plants compact about 2-3 weeks after forcing begins.

10. DISEASE AND INSECT PESTS

Coreopsis 'Moonbeam' is generally considered a trouble-free species, but we have noted powdery mildew on a few occasions.

11. POSTHARVEST CONCERNS

Coreopsis 'Moonbeam' should be shipped just after the first flower opens. 'Moonbeam' is most salable in full flower, which occurs about 7 days after first flower. Plants also tend to become floppy the longer they are held after first flower.

Coreopsis 'Moonbeam' can be cut back after the initial flush of flowers for a repeat of full bloom. Plants will continue to flower if provided bright light, continual long days, and sufficient water. They can be enjoyed in the garden for many years. **GG**

About the authors: Cheryl K. Hamaker is a graduate student, and Drs. Royal Heins, Will Carlson, and Art Cameron are professors of horticulture, Department of Horticulture, Michigan State University, East Lansing, MI 48824.
They thank generous industry supporters who made possible the research this article is based on, as well as Paul Koreman, Erik Runkle, Cara Wallace, Tom Wallace, and Cathy Whitman.

Figure 1.

– Crop By Crop –

FORCING PERENNIALS

Species: *Delphinium grandiflorum* 'Blue Mirror'
Common name: Delphinium

by ***ALISON FRANE, SHI-YING WANG, ROYAL D. HEINS, WILL CARLSON,*** *and* ***ARTHUR CAMERON***

THE tall spikes of delphinium are popular as a backdrop in many a perennial garden. Although cultivated in gardens since 1578, delphinium, along with hundreds of other perennial species, is experiencing a resurgence in popularity (Figure 1).

The name delphinium comes from the Greek for "Dolphin flower," perhaps because of the shape of the spur on the upper part of the flower. The showy parts of the inflorescence are not actually petals, but bracts – modified leaves that form below the flower. The petals themselves are often of a contrasting color, clustered in the throat of the flower and are sometimes called the "bee."

There are many "wild-type" delphiniums that are sometimes grown in the garden, but most of our horticultural cultivars come from *Delphinium elatum* (e.g. 'Blue Nile,' 'Magic Fountains,' and the Pacific series). These have tightly packed spikes of flowers, and come in a wide variety of colors, ranging from white to light blue and pink to purple and "true blue." Other species in cultivation include *Delphinium grandiflorum* ('Blue Butterfly' and 'Blue Mirror') with flowers in looser spikes, and *Delphinium x belladonna*, a hybrid of *D. elatum* and *D. grandiflorum*.

Figure 2.

Figure 2. *Delphinium grandiflorum* 'Blue Mirror' can be successfully grown as a bench-run crop. Shown here planted in 4-inch pots, these plants were given 5 weeks of cold treatment at 35°-41°F (0°- 5°C), followed by forcing under natural days at about 68°F (20°C).

Most of our research has been conducted on *D. grandiflorum* 'Blue Mirror' (Figure 2), although other cultivars have been used in some experiments. While we expect responses to be similar, we have found that cultivars often vary in their response.

The information provided here is for *D. grandiflorum* 'Blue Mirror' only, unless otherwise stated. 'Blue Mirror' is a day-neutral plant that can bloom without cold, but benefits from a short cold treatment to shorten flowering time in the greenhouse. Another cultivar, *D. elatum* 'Magic Fountains' is also day-neutral but requires cold to flower.

1. Propagation

'Blue Mirror' is commercially propagated from seed, although germination percentages are typically lower – 60%-70%. The seeds need no particular pretreatment, but if stored should be kept cool and dry. It is commonly double-sown into a 128-cell flat and germinated in the dark at 60°-65°F (15°-18°C). Emergence usually occurs in 12-14 days, and the total time for the crop is about 8 weeks.

Figure 3.

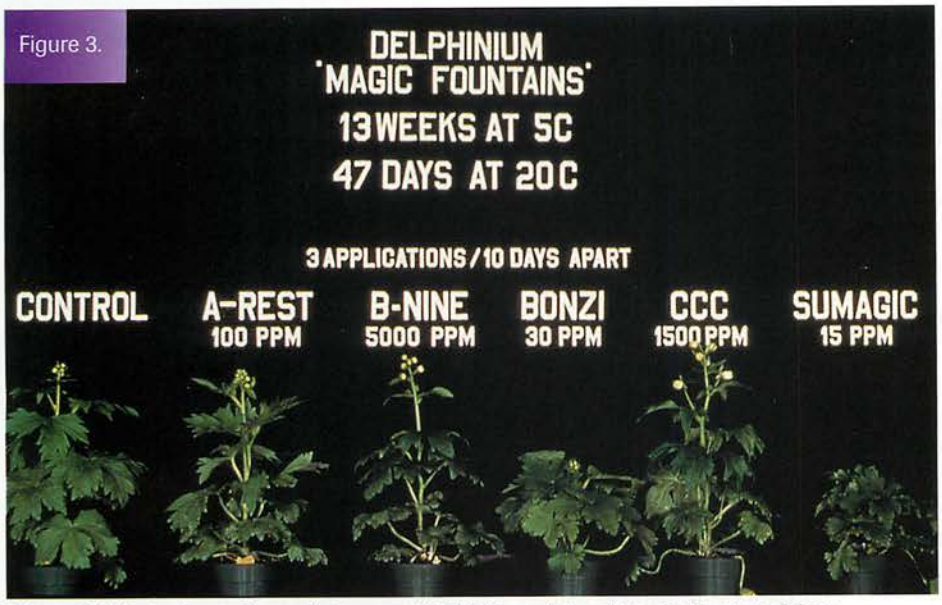

Figure 3. Effect of growth regulators on *Delphinium elatum* 'Magic Fountains' (not flowering): Although we have not performed a formal growth regulator screen on the cultivar *D. grandiflorum* 'Blue Mirror,' we have found that *D. elatum* 'Magic Fountains' responds best to Sumagic and Bonzi.

2. Plant Size

'Blue Mirror' does not appear to have a juvenility period: starting material with as few as four or five leaves will go on to flower. It bolts before blooming, and so doesn't increase in lateral vegetative size as such. Since the basal rosette is rather small, this plant may look better planted in a 4-inch pot, or with multiple plants in a 6-inch or gallon pot. More plants per pot also helps to prevent overwatering.

3. Cold Treatment

A 5-week cold period at about 32°-41°F (0°-5°C) is recommended for 'Blue Mirror.' A longer cold treatment nominally decreases days to flower. Plants can be

Figure 4.

Figure 4. *Delphinium grandiflorum* 'Blue Mirror' flowers fastest at 74°F (23°C). Warmer temperatures cause heat delay, and cooler temperatures slow development. Plants were much more attractive at lower temperatures, however, with larger, more abundant flowers.

successfully cooled in a plug tray, provided that they do not experience drought stress.

'Blue Mirror' will flower without a cold treatment, but flowering time is approximately 2 weeks sooner after a 5-week cold treatment. Flower number is similar with and without a 5-week cold treatment. *Delphinium elatum* 'Magic Fountains' will not flower without a cold requirement to flower. We recommend 10-15 weeks at 26°-41°F (0°-5°C).

4. Photoperiod

'Blue Mirror' is a day-neutral plant and as such will flower under any photoperiod. Short days slowed development slightly, but increased flower number. The use of night lighting treatment with incandescent lights is not recommended, as it increases plant height. We, therefore, suggest natural daylengths.

5. Media, Fertilization, And Irrigation

In our experiments, we have had good results with pH between 5.8 and 6.4 and moderate nutrient supplementation. We used a fertilizer solution containing 100-150 ppm N, 10-20 ppm P, and 100-150 ppm K at every irrigation.

Because of its propensity to develop root rot (Pythium sp.), a well-drained media is essential for delphinium. Overwatering can exacerbate root or crown rot, especially when plants are on the small side for the pots (e.g. early in production) or when growth is slowed by cooler temperatures or pH problems.

6. Lighting And Spacing

Delphinium prefers sun, and supplemental lighting from high-pressure sodium lamps at 400-500 footcandles improves quality in the greenhouse, especially during the winter months. 'Blue Mirror' has an upright and open growth habit, so plants can be spaced fairly closely. Don't space too closely, however, or the flower spikes may become tangled.

7. Plant Height Control

'Blue Mirror' is a naturally tall plant, and is beautiful when used accordingly in the landscape. In a pot, however, we have observed heights up to 20 inches that are decidedly unwieldy. Add to this the fact that it is quite weak stemmed, and often requires staking, and you have a strong argument for height reduction.

While we have not performed a formal growth regulator screen on *D. grandiflorum* 'Blue Mirror,' B-Nine at 3000 ppm was found to be quite effective when used in our bench-run forcing. Further research with growth regulators will be necessary on this species. In a growth regulator screen on *D. elatum* 'Magic Fountains,' Bonzi and Sumagic were found to be the most effective chemical growth retar-

Figure 5.

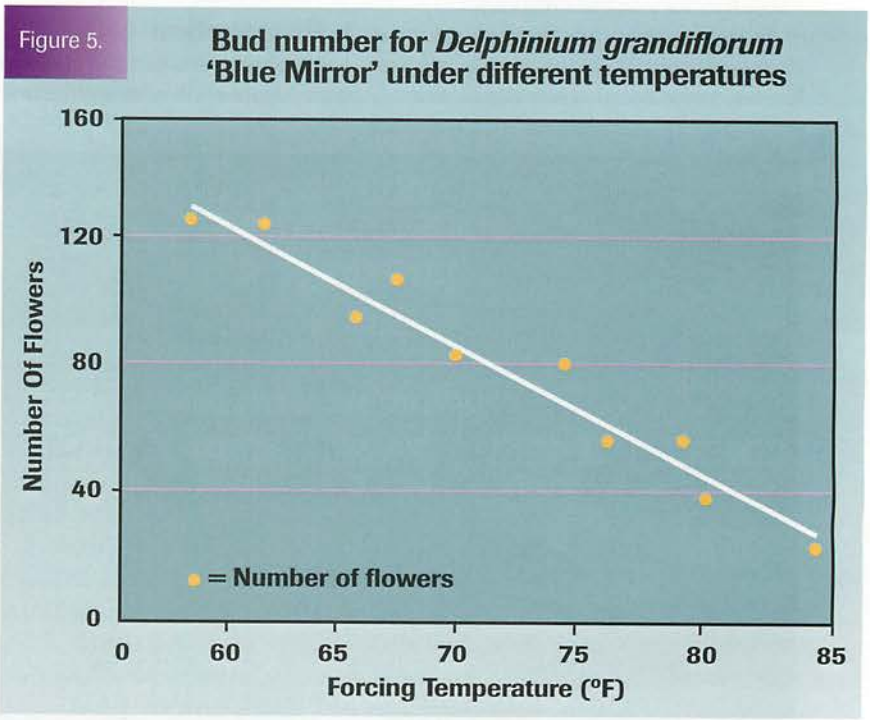

Figure 5. Number of flowers was strongly affected by forcing temperature. Plants grown at cooler temperatures had more than 120 flowers, while at warmer temperatures there were fewer than 40.

Table 1. *Delphinium grandiflorum 'Blue Mirror' Production Schedule*

Growing time	Cultural practice	Temperature	Photoperiod
12-14 days	Sow seeds Germination	60°-65°F (15°-18°C)	Darkness
6 weeks	Grow on in plugs	60°-65°F (15°-18°C)	Natural daylength
	-OR- Purchase plugs		
5 weeks	Cold treatment	35°-45°F (2°-7°C)	Natural daylength or 9 hours of light in the cooler
Begin forcing			***Natural daylength***
↓ ↓ ↓ ↓ ↓ ↓ 59°F (15°C) Flower in 92 days (13 weeks)	↓ ↓ 64°F (18°C) Flower in 77 days (11 weeks)	↓ 70°F (21°C) Flower in 69 days (10 weeks)	***Number of days from visible bud to flower*** 59°F (15°C) - 32 days 64°F (18°C) - 27 days 70°F (21°C) - 21 days

dants (Figure 3).

Negative DIF (the DIFference between night and day temperatures) was mildly effective on *Delphinium x belladonna* (a.k.a. *D. elatum* 'Belladonna') and can reduce its height by several inches.

8. Temperatures And Crop Scheduling

Delphinium performs best at cooler temperatures. We found that 'Blue Mirror' bloomed fastest at 74°F (23°C), but had the most flowers at the lowest temperature we tested, 59°F (15°C) (Figure 4). Plants forced at higher temperatures expressed heat delay and were smaller and had fewer buds than at the lower temperatures (Figure 5). We suggest forcing cooler for higher quality plants with more flowers.

9. Disease And Insect Pests

Problems with root rot, particularly Pythium, have been repeatedly noted. This can be prevented by using a well-drained media and the right plant-to-soil ratio (number of plants per pot and pot size). Apply regular fungicidal drenches for control of Pythium, starting at transplant, and monthly thereafter.

Young plants are sometimes chlorotic, for unknown reasons, but we have not found that this affects final quality. Although we have had no significant problems with insect pests in our experiments, scouting and other preventative maintenance practices should always be followed.

Formula For Success: 'Blue Mirror'

1. Use a well-drained media and watch out for overwatering. Delphinium is quite susceptible to root rot.

2. Provide 5 weeks of cooling at 41°F (5°C) before forcing.

3. Keep the greenhouse below 65°F (18°C) for forcing. Plants at lower temperatures were more attractive and had larger and more abundant flowers.

4. Provide natural photoperiods.

5. Provide high-intensity supplemental lighting if forcing in midwinter

6. Apply growth retardants when stem starts to elongate. Staking may be necessary.

10. Postharvest Concerns

'Blue Mirror' should be shipped just before first bloom as the first flowers open in sequence within a matter of days. Spent flowers are dropped and may look unattractive scattered about. The plant continues to bloom for several weeks. Staking is often necessary, even on small plants, as they can be weak stemmed and top heavy. **GG**

About the authors: Alison Frane is a graduate research assistant, Dr. Shi-Ying Wang is a research associate, and Drs. Royal D. Heins, Will Carlson, and Arthur Cameron are professors of horticulture, Department of Horticulture, Michigan State University, East Lansing, MI 48824.

– Crop By Crop –

FORCING PERENNIALS

Species: *Echinacea purpurea* 'Bravado'
Common name: Purple Coneflower

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

ALWAYS a showstopper in the garden, *Echinacea purpurea*, or purple coneflower, provides long-lasting color throughout the summer. Echinacea, a member of the Asteraceae or sunflower family, is native to the prairies and dry plains of North America. The plants are upright, clump-forming, and produce hairy, coarsely toothed basal leaves that grow 6 inches long.

Large flowers are born atop sturdy stalks reaching up to 4 feet. The flower heads consist of a raised central cone of bronze-colored disc flowers encompassed by intensely colored ray florets. Coneflowers grow in USDA Zones 3-10 and perform best in full sun and well-drained soil.

The most common cultivars of *Echinacea purpurea* are 'Bravado,' 'Magnus,' and 'White Swan.' 'Bravado' (Figure 1) is a sturdy cultivar with a deep bronze-colored cone and slightly reflexed rosy red petals. 'White Swan' features gold to brown-colored cones with white petals. 'Magnus,' chosen as the Perennial Plant Association plant of the year for 1998, has a petal display that is distinct from other cultivars. Rather than the drooping ray florets characteristic of many Echinacea, 'Magnus' sports wide, flat, and more upright deep pink petals.

There are several other available species of Echinacea, including *E. angustifolia*, a narrow-leafed purple coneflower; *E. pallida*, a pale purple coneflower with strongly reflexed petals; and *E. paradoxa*, a rare species with bright yellow-ray flowers. Cultivars of the species *Echinacea purpurea* are the most popular choices for the garden.

Figure 1.

Figure 1. *Echinacea purpurea* 'Bravado' makes an excellent flowering potted perennial.

All suggested production information is based on observed responses of *E. purpurea* 'Bravado.' Because flowering requirements within Echinacea could vary, other species and cultivars of Echinacea may not respond in the same manner. But ongoing studies with 'Magnus' show a very similar response to that of 'Bravado.'

1. Propagation

Echinacea purpurea 'Bravado' may be propagated by seeds, basal cuttings, rooted cuttings, or division. Most Echinacea produced commercially are propagated from seed, although 'Magnus' is propagated vegetatively. Seeds must be moistened and stratified for 4 weeks at 40°F. Germinate seeds between 65°F and 70°F (18°-21°C) in a moist medium. Seeds can be exposed to light or covered lightly during germination. Seedlings should be grown at cool temperatures (70°F) and transplanted after 6-8 weeks.

Cuttings can be removed in spring when shoots are 4-6 inches long and treated with 1000 ppm IBA in powdered form. Root propagation can be performed by taking pencil-sized root sections during late fall or early winter. Cover root sections with medium and hold at 60°F. Divide clumps in early spring.

2. Plant Size

Juvenility is not a significant problem for flowering *E. purpurea* 'Bravado.' Seedlings with only four leaves (128-cell plugs) flowered under a 14-hour photoperiod or with a 4-hour night interruption (NI), both provided with incandescent bulbs. 'Bravado' is best suited to 6-inch or 1-gallon pots with three plants per pot. A finished plant can grow as tall as 40 inches (100 centimeters). We have found that height increases with increased container size.

3. Cold Treatment

Cold treatment is not necessary for flowering of 'Bravado,' but plants flower 2-3 weeks earlier following a 10-week cold treatment at temperatures between 32°F (0°C) and 45°F (7°C) in a minimally heated greenhouse or lighted cooler. Extending the cold treatment to 15 weeks decreases the time to flower slightly further, but it is not necessary. Plugs tolerate cold temperatures well if plants are not stressed. Overwatering can cause rot and disease problems. In our coolers, plugs received 9-hour days with about 50 footcandles of light from cool-white fluorescent lamps. Higher light levels in a cold greenhouse are not a problem.

Figure 2a.

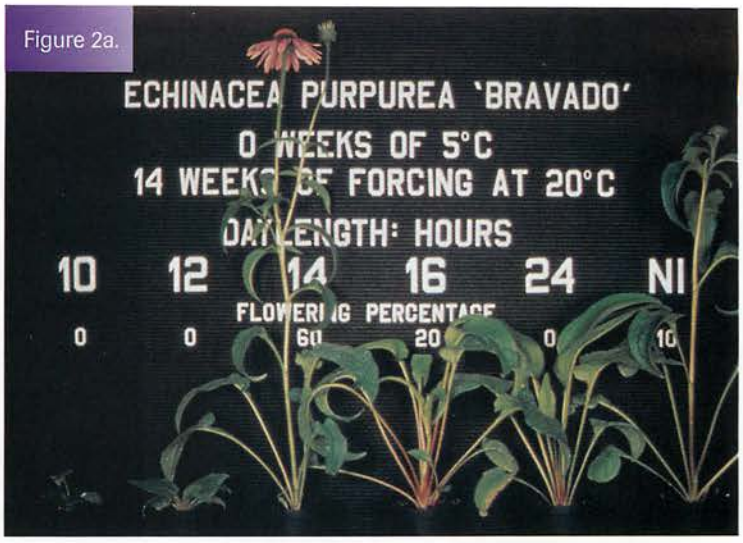

Figure 2a. Influence of different photoperiods on flowering of *E. purpurea* 'Bravado.' The plants shown received no cold treatment and were placed directly into a 68°F (5°C) greenhouse under seven different photoperiods. The highest percentage of flowering occurred under 14 hours. *Photos 2a. and 2b. courtesy of Erik S. Runkle.*

Figure 2b.

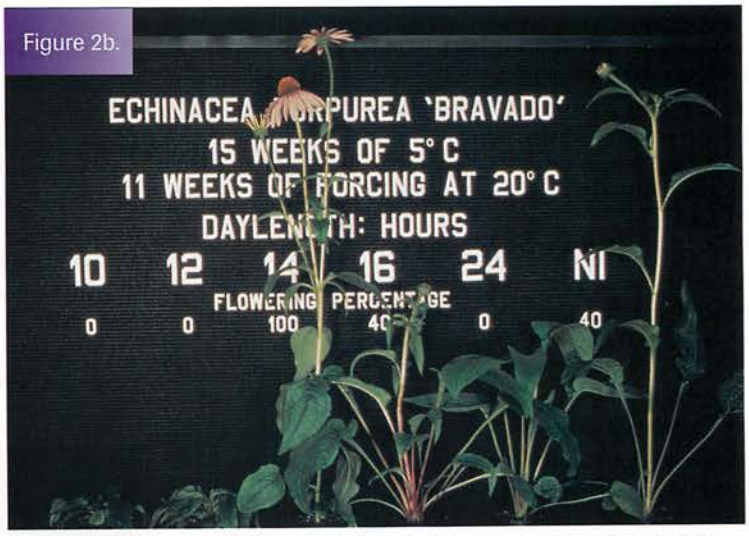

Figure 2b. Influence of different photoperiods on flowering of *E. purpurea* 'Bravado.' The plants shown received a 15-week cold treatment at 41°F (5°C) and then were grown in a 68°F (20°F) greenhouse under seven different photoperiods. 100% flowering occurred under 14 hours.

4. Photoperiod

'Bravado' is an intermediate-day plant. This means plants flower the most completely, rapidly, and uniformly under an intermediate photoperiod. Plants exposed to 12 hours of light or less, or 16 hours of light or longer, flower poorly. No flowering is observed under continuous light. The most rapid and uniform flowering occurs when plants are exposed to 14-hour photoperiods (Figures 2a and 2b). Night-interruption lighting (NI) is also effective in promoting flowering.

While 30 minutes to 4 hours of NI are effective, plants are much shorter when given only 30 minutes of NI (Figure 3). When photoperiods are 12 hours or less, we recommend providing NI lighting for 30-60 minutes during the middle of the dark period. Plants exposed to 4 hours of NI lighting will also flower, but they will be taller. Avoid photoperiods longer than 15 hours because not all plants will flower.

5. Lighting And Spacing

In the garden, 'Bravado' grows best with full sun, but it will tolerate par-

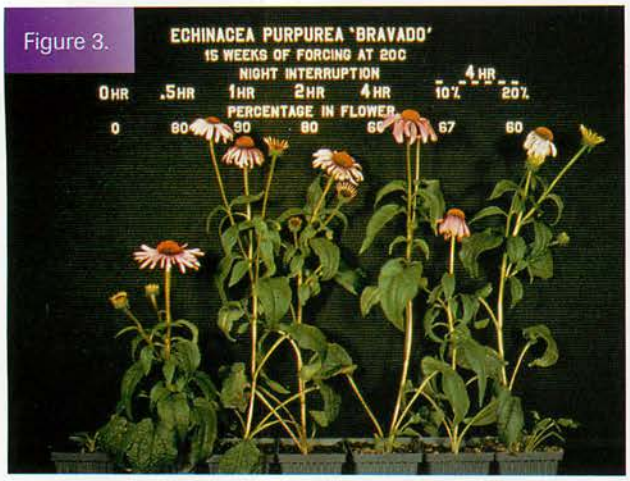

Figure 3. Influence of cyclic lighting on flowering of *E. purpurea* 'Bravado.' Plants were much shorter when given only 30 minutes of NI lighting during the middle of the dark period. *Photo courtesy of Erik Runkle.*

Figure 4. Influence of plant growth regulators on the height of *E. purpurea* 'Bravado.' Only Bonzi was ineffective in controlling plant height. But leaf discoloration may occur when using Cycocel. Proper timing of the applications is critical for successful height control. The rates indicated are not necessarily those recommended. *Photo courtesy of Erik Runkle.*

tial shade. In the greenhouse, high light levels are recommended, and supplemental lighting from high-pressure sodium lamps will improve the quality of the crop during dark winter months. Space 5-inch pots on at least a 7-inch center. Adequate spacing helps minimize the likelihood of disease and, more importantly, it reduces stretching.

6. Media, Fertilization, And Irrigation

'Bravado' is well-adapted to dry areas and soils that provide good drainage. Plants should not be allowed to sit in excess water. Echinacea, though, require large quantities of water once they begin to bolt, especially at warm temperatures. 'Bravado' grows well in a soilless media and at a pH of 6.0 or slightly above. Problems with 'Bravado,' such as leaf distortion, can occur when the pH drops below 6. A constant feed of 100-150 ppm from a balanced fertilizer (e.g., 20-10-20) is adequate for good growth.

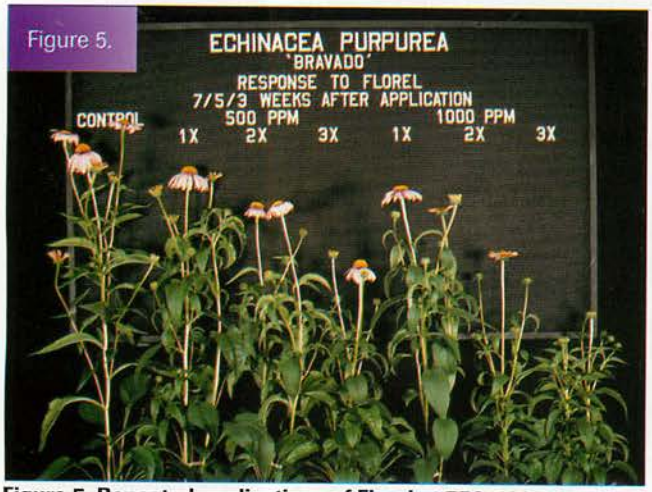

Figure 5. Repeated applications of Florel at 750-1000 ppm can control height of 'Bravado.' *Photo courtesy of Takahiro Hayashi.*

7. Plant Height Control

One of the major difficulties in forcing *E. purpurea* in containers is producing a plant that is not too tall for the pot. Plants may reach 40 inches in a pot. We have found that growth regulators can effectively reduce plant height. Application timing is critical for success, and repeated applications are required when plants begin to bolt. A-Rest, B-Nine, Cycocel, and Sumagic all controlled plant height (Figure 4), but Cycocel can cause leaf discoloration in 'Bravado.'

Late applications of B-Nine or Cycocel can also cause deformed inflorescences or black-tipped petals. Florel at 750-

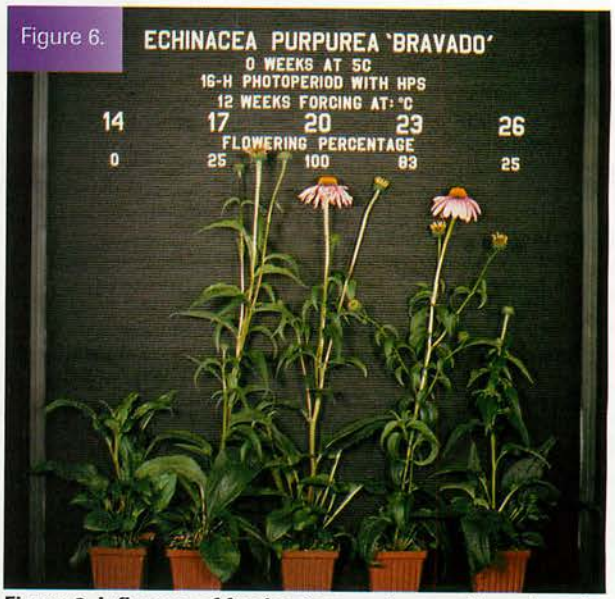

Figure 6. Influence of forcing temperature on flowering of *E. purpurea* 'Bravado.' Plants flowered quickest at temperatures below and above this range. *Photo courtesy of Erik Runkle.*

Table 1. **Echinacea purpurea 'Bravado' Production Schedule**

Growing Time	Cultural Practice	Temperature	Photoperiod
4 weeks	Chill seeds	40°F (4°C)	Any
2 weeks	Sow seeds Germination	68°F (20°C)	Natural daylengths
	– OR – *Purchase Plugs*		
6-8 weeks	Grow until at least four leaves have formed	68°F (20°C)	Daylengths ≥14 hours or night interruption
	Begin Forcing		***14 hours of light or a 30-minute to 4-hour night interruption***
↓ ↓ ↓ 63°F (17°C) Flower in 17-18 weeks	↓ 68°F (20°C) Flower in 14-15 weeks	↓ 73°F (23°C) Flower in 14-15 weeks	***Number of days from visible bud to flower*** 63°F (17°C) - 27 days 68°F (20°C) - 25 days 73°F (23°C) - 24 days

1000 ppm applied every 2 weeks beginning at the start of bolting controls stem elongation (Figure 5).

Short durations of NI lighting can effectively control height with little or no delay in flowering when plants are flowered under short day conditions. Usually, 30 minutes of NI lighting using incandescent lights or high-pressure sodium lamps at 10 footcandles is sufficient to produce uniform flowering. Using short durations of NI lighting is not helpful during long summer days.

8. Temperatures And Crop Scheduling

Under inductive photoperiods, the average daily temperature is the primary factor influencing time to flower. Increasing the temperature usually decreases time to flower, and while this may seem desirable, delayed flowering and diminished plant quality may result.

Noncooled plants of 'Bravado' with four leaves, grown under optimum day lengths (14 hours or with a NI of 30-60 minutes), take 17-18 weeks at 64°F (17°C), and 14-15 weeks at 68°-73°F (20°-23°C) to flower (Figure 6, Table 1). Plants develop very slowly at 60°F (14°C) or lower. Temperatures above 79°F (26°C) reduce flower quality and uniformity and should be avoided. We have not determined if cooler night temperatures can overcome detrimental effects of high day temperatures. Cooled plugs flower 2-3 weeks faster at all forcing temperatures.

Formula For Success: Purple Coneflower

1. Match starting material to desired final size. 128-cell plugs are appropriate for 4- or 5-inch pots. Larger plugs are suitable for 1-gallon pots.

2. Provide plants with 14-hour photoperiods or short durations (30-60 minutes) of NI lighting after the cold treatment, with a minimum light intensity of 10 footcandles.

3. Provide plants with supplemental lighting from high-pressure sodium lamps during the dark winter months.

4. For greatest height control, apply growth regulators when plants begin to elongate.

5. Force between 64°F and 74°F (17°-23°C).

9. Disease And Insect Pests

We have observed very few insect or disease problems with 'Bravado,' but slugs or aphids can cause problems. Echinacea is susceptible to "yellows" disease, which is caused by pathogenic microorganisms called phytoplasmas, and it is spread by leafhoppers. Affected plants generally show leaf yellowing, reddening, and stunting in the early stages of disease development. Plants may have extremely numerous, small, and branched axillary shoots coming from the nodes, giving them a "bunchy" appearance. Flowers may also appear bunched.

10. Postharvest Concerns

'Bravado' has a bloom season of 6 weeks or longer. Lower leaves may become unsightly with time, especially if plants are crowded. In addition, flowers that open under low light conditions have decreased size and color intensity. **GG**

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– Crop By Crop –

FORCING PERENNIALS

Species: *Gaillardia x grandiflora* 'Goblin'
Common Name: Blanket Flower

by ***MEI YUAN, ROYAL D. HEINS, WILL CARLSON,*** *and* ***ARTHUR CAMERON***

Figure 1.

Gaillardia x grandiflora **is a very attractive plant in the landscape.**

GAILLARDIA X GRANDIFLORA is a very common herbaceous perennial, albeit relatively short-lived. In the summer, this species from the aster family produces large, showy flowers that are usually red or red with yellow rings (Figure 1). The beautiful, daisylike inflorescences make long-lasting cut flowers. Blanket flower is a hybrid between *G. aristata* and *G. puchella* and now has naturalized in the western U.S. It is fully hardy from zones 4 through 8. Plants can grow 2 feet tall in natural conditions and usually need staking because of their long, tender stems. It is a very showy potted plant when in flower.

Cultivars

'Goblin' is the most common cultivar and has red flowers with yellow rings. Plant populations exhibit some morphological variability such as plant height, leaf shape, and flower color. Some plants may have double flowers. 'Dazzler' bears yellow-tipped red flowers, while 'Wirral Flame' is a short-lived perennial with deep cardinal-red flowers.

Flower Induction Requirements

The following production information is based on 'Goblin' and may not apply to other cultivars. To flower, *Gaillardia x grandiflora* 'Goblin' must be

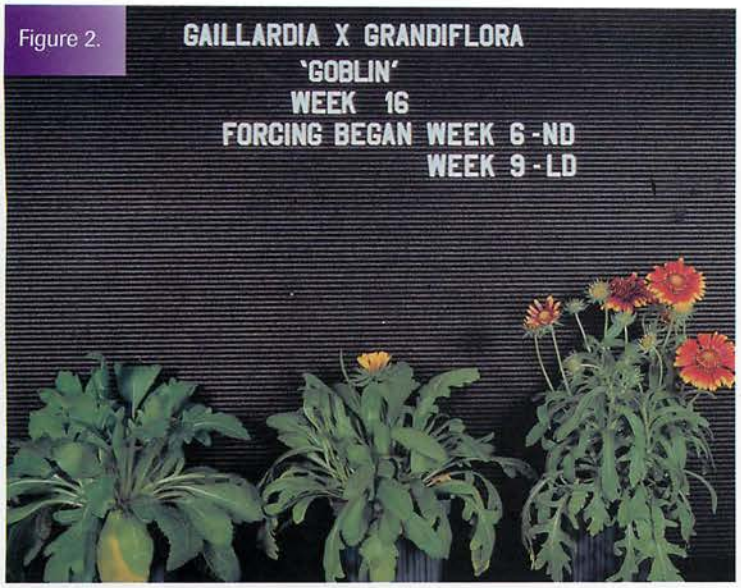

Figure 2.

Example of variability that can occur in *Gaillardia x grandiflora* 'Goblin' populations, especially when leaf number at the start of cold is low. These plants averaged about 10 leaves at the start of cold and were placed under long days at week 9. The photo was taken 7 weeks later.

mature before being exposed to cold treatment and then long days. Compared to many other species where 100% flowering is possible on uniform-looking plants, flowering of 'Goblin' populations is often less than 100%, and morphology of plants that do flower tends to vary (Figure 2).

1. PLANT SIZE

'Goblin' has a distinct juvenility phase after germination, during which plants should be grown under photoperiods shorter than 14 hours. While individual plants will flower when smaller, most of a population reaches maturity when each plant has developed about 16 nodes (visible leaves).

2. COLD TREATMENT

'Goblin' requires cold treatment for fast and uniform flowering (Figure 3). A 10-week cold period at about 41°F (5°C) in a cold greenhouse or cooler is recommended for flower induction. We have found extending the cold period from 10 to 15 weeks will enhance flowering percentage on marginally mature plants and result in more flower buds.

3. PHOTOPERIOD

Horticulturally, 'Goblin' is an obligate long-day plant. Fast uniform flowering occurs when plants are exposed to long days (16 hours or more) or night-interruption lighting for 4 hours from 10 p.m. to 2 a.m. Flowering can occur under short days (Figure 4), but flowering is delayed and less uniform, and the flowering percentage and number of flowers per plant is low compared to that of plants grown under long days.

4. PROPAGATION

'Goblin' can be propagated by seed or division (Figure 5). Division is used most commonly by gardeners for rejuvenation and plant-size control, preferably in the spring. Seed propagation is used widely for commercial production. Seeds germinate in the light at 70°-75°F (21°-24°C) and high humidity (90%-95%). Seedlings emerge within 5-15 days. After germination, humidity should be lowered to 85%-90%.

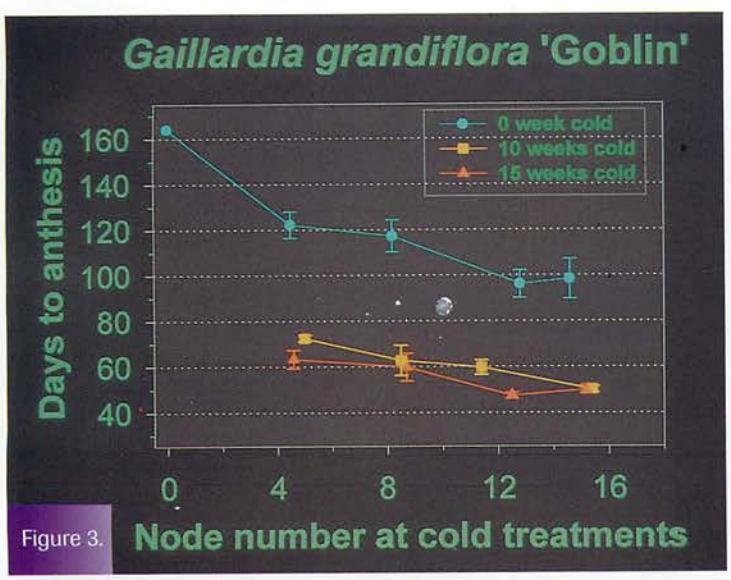

Figure 3.

Relationship between node (leaf) number at the start of cold and time to flower for *Gaillardia x grandiflora* 'Goblin.' Flowering is hastened about 50 days by a 10- or 15-week cold treatment. Flowering percentage was also less than 50% without a cold treatment.

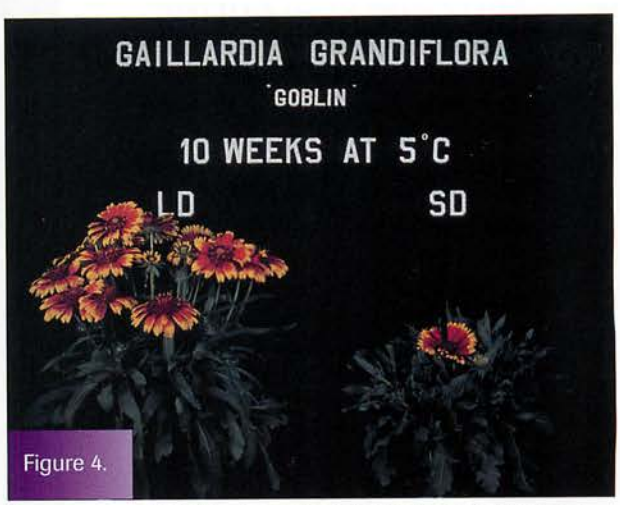

Figure 4.

Appearance of *Gaillardia x grandiflora* grown under long days (LD) or a 9-hour short day (SD). Plants grown under long days flower quicker and more abundantly.

5. MEDIA AND FERTILIZATION

'Goblin' prefers well-drained medium with a pH of 5.8-6.4. Fertility should be moderate; constant fertilization at 100-200 ppm N from a balanced fertilizer is adequate.

6. LIGHTING AND SPACING

'Goblin' requires bright light. Supplemental lighting from high-pressure sodium lamps at 400-500 footcandles accelerates development and improves quality during winter. Spacing plants properly can minimize the incidence of disease and insect pests.

7. IRRIGATION

Frequent irrigation is required during hot, sunny days. On bright days, plants may wilt before the medium dries because of their large leaf area.

8. PLANT HEIGHT CONTROL

'Goblin' tends to be too tall when grown in 4- or 6-inch pots and usually needs staking. Unfortunately, we have not observed any significant height reduction when using any growth retardant.

9. TEMPERATURES AND CROP SCHEDULING

After germination, plants should be grown at 70°-75°F (21°-24°C) to shorten the juvenile phase. However, the plants do not tolerate high temperatures well from forcing to flower. Temperatures higher than 75°F (24°C) will delay time to flower and reduce quality, so 18°-20°C (65°-68°F) is optimum.

Once long-day forcing begins after cold, time to flower depends on the forcing temperature. Allow 9-10 weeks at daily averages of 60°F (15°C), 7-8 weeks at 65°F (18°C), or 6-7 weeks at 70°F (21°C) (Table 1). Remember, these are 24-hour averages, not just day or night temperatures.

Time to flower and flowering percentage among seed-propagated 'Goblin' plants are highly variable within a population and between years. Older plants flower more uniformly.

Consider using field-grown plants or 21/4-inch plugs for most uniform flowering. Plants can be purchased in 128-cell, 50-cell, or 21/4-inch plugs or as field-grown bare-root plants (Figure 5).

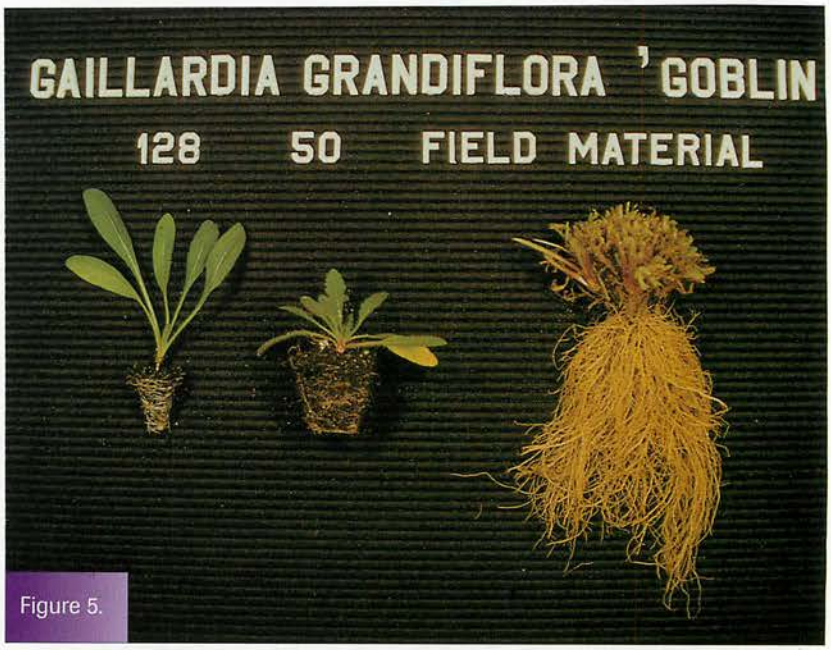

Figure 5.

Appearance of plant material at the start of cold treatment for plants shown in Figures 6 and 7. The 128 and 50 represent the number of plants per plug tray.

Bare-root plants can make very attractive finished plants (Figures 6 and 7) and are ideal for 1-gallon or larger containers, but bare-root materials may deteriorate during cold storage unless they are planted first.

All plugs can be stored directly in coolers. Final plant size will depend on the size of the plant at the start of long days.

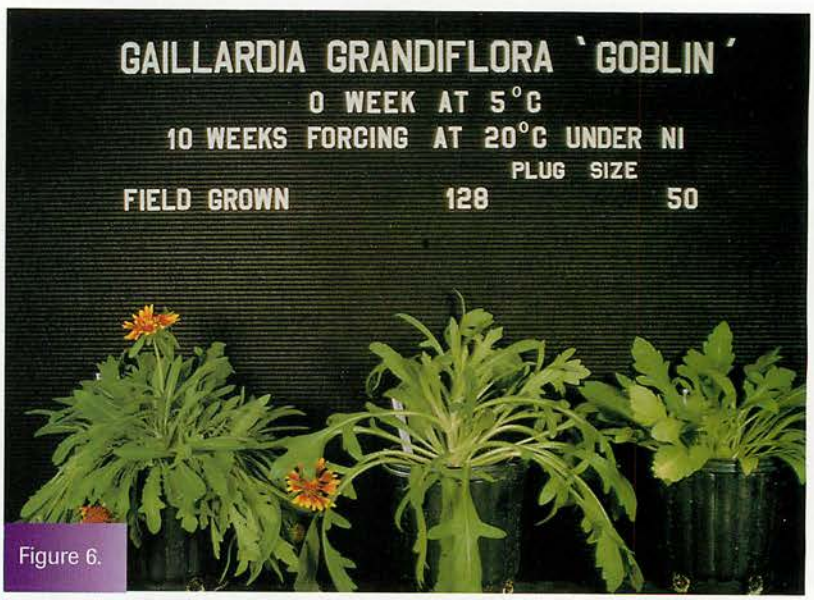

Figure 6.

Appearance of *Gaillardia x grandiflora* 'Goblin' after 10 weeks of greenhouse forcing under long days. Plants did not receive a cold treatment. Flowering, at best, was sporadic. Plant size is described in Figure 5.

Table 1. ***Gaillardia x grandiflora*** **'Goblin' Production Schedule**

Growing Time	Cultural Practice	Temperature	Photoperiod
1 week	Sow seeds ↓ Germination OR purchase plugs	68°-72°F (20°-22°C)	Natural day length
9-10 weeks	Grow until at least 16 leaves have formed	72°-76°F (22°-24°C)	<12 hours of light
10-15 weeks (Can be held longer if needed)	Cold treatment ↓	35°-45°F (1°-7°C)	Natural day length or 9 hours of light in cooler
	Begin Forcing		>16 hours of light or a 4-hour night interruption
↓ ↓ ↓ 60°F (15°C) 9-10 weeks flower	↓ ↓ 65°F (18°C) 7-8 weeks flower	↓ 70°F (21°C) 6-7 weeks flower	**Visible Bud to Flower** 60°F (15°C) – 20 days 65°F (18°C) – 18 days 70°F (21°C) – 14 days

10. DISEASE AND INSECT PESTS

'Goblin' plants are susceptible to aphids, especially in crowded humid conditions. Aster yellows and powdery mildew may be problematic also.

11. POSTHARVEST CONCERNS

For a long shelf life, the plants should be shipped when the first flowers open. If the plants are not sold soon after first flower, dead-heading will be necessary to remove spent flowers.

Ideally, dead-heading would not be necessary; however, nonuniformity in populations can be so great that the first flowering plants will require dead-heading before the last plants in the population flower.

Flowering will continue if spent flower heads are dead-headed and enough light and water are provided. Flowering ceases if spent flowers are not removed. **GG**

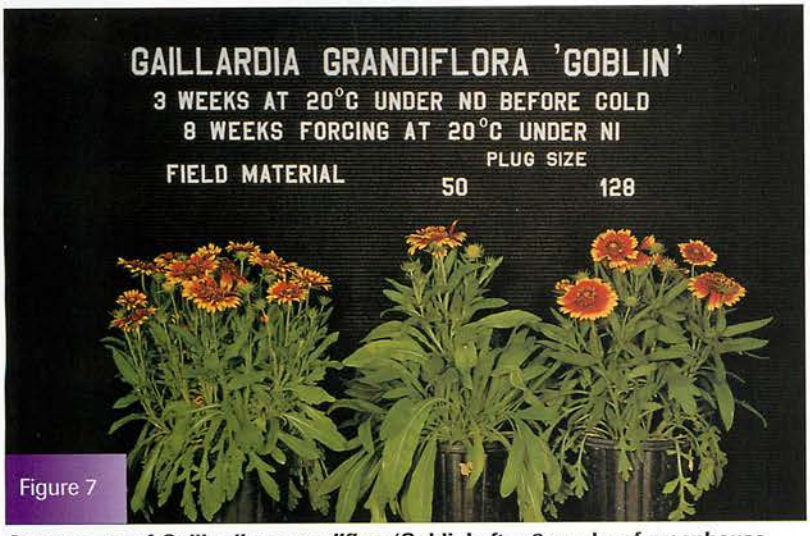

Figure 7

Appearance of *Gaillardia x grandiflora* 'Goblin' after 8 weeks of greenhouse forcing under long days. Plants were potted, grown for 3 weeks under normal photoperiods (ND) in October, then given a cold treatment for 13 weeks before forcing. Growth prior to cold is necessary only if plants are still juvenile (i.e., they have not yet developed 16 leaves). Plant size is described in Figure 5.

Formula For Success: 'Goblin'

1. Force only plants with 16 or more nodes (leaves).

2. Provide plants at least 10 weeks' cold treatment at 41°F (5°C) before long-day treatment.

3. Force at 60°-70°F (15°-21°C).

4. Grow plants under long days after cold treatment. Long days can be provided by natural or extended photoperiods of at least 16 hours or by night interruption from 10 p.m. to 2 a.m. with a minimum of 10 footcandles of light.

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– Crop By Crop –

FORCING PERENNIALS

Species: *Gaura lindheimeri* 'Whirling Butterflies'
Common name: Gaura

by ***LESLIE FINICAL, ARTHUR CAMERON, ROYAL D. HEINS, WILL CARLSON,*** *and* ***KEVIN KERN***

GAURA LINDHEIMERI is not yet ranked with the most popular of herbaceous garden perennials, such as daylilies and hosta. But there is always room in the garden for a tough, low-maintenance, and beautiful plant like gaura (Figure 1).

Native to Texas and Mexico, gaura is versatile, resilient, and it will grow in climates ranging from USDA zones 5-10. Gaura usually ranges in height from 3- to 4-feet tall and is excellent for group plantings, rock gardens, or as filler for dull landscape spots. Flowers range in color from white to pale pink, and even yellow in one species.

G. lindheimeri 'Whirling Butterflies' is a white-flowered selection that is a great performer in the garden. 'Whirling Butterflies' has small flowers that it bears atop tall, thin stems. The foliage is dark green, which makes for an attractive contrast to the brilliant white flowers. The leaves are lanceolate and about $2^1/_2$-$7^1/_2$ centimeters long. Foliage may turn a deep purple color as temperatures decrease in the fall and winter. Although individual plants do not spread rapidly, gaura seeds freely.

'Siskiyou Pink' is a pink-flowered cultivar of *G. lindheimeri.* This beautiful cultivar originated at the Siskiyou Rare Plant Nursery in Oregon as a chance seedling. Flowers open deep pink from red buds, fading to pale pink and then white as the flowers age. The foliage is dark green with pink veins and has a mottled appearance.

The information provided in this article applies to *G. lindheimeri* 'Whirling Butterflies' only. We have not conducted any research on the cultivar 'Siskiyou Pink.'

Figure 1.

Figure 1. A nonstop bloomer, *Gaura lindheimeri* 'Whirling Butterflies' is an excellent addition to any forcing program. *Photo courtesy of Leslie Finical.*

1. Propagation

In the garden, *G. lindheimeri* can be propagated by division in spring or fall, or by seed. Plant division helps rejuvenate old clumps and increases or controls the number of plants. Clumps are best divided in early spring or after flowering.

Commercially, *G. lindheimeri* is vegetatively propagated by stem cuttings, division, and by seed. Vegetative cuttings are generally preferred over seedlings because they are true to type. Growers take vegetative cuttings in the summer when days are long. Plants grown under short days are diminutive in size and do not produce many lateral branches.

Obtaining production-quality cuttings from *G. lindheimeri* is fairly simple. In one experiment, we propagated plants by taking $1^1/_2$- to 2-inch soft-tissue cuttings from plants grown under 16-hour days (performed week 2 of the calendar year).

We dipped each cutting in a 0.1% IBA powder. Cuttings were grown under 10-hour natural days with mist for about 1 week. Cuttings left under the mist longer usually died. We observed the first signs of rooting within 7 days. At only 3 weeks of age (week 5), we placed our new plugs into a 41°F (5°C) lighted cooler for 6 weeks.

While in the cooler, plugs received 9-hour days from fluorescent bulbs at

approximately 50 footcandles. Even at such a young stage, the plugs tolerated the cold treatment very well. We then planted the plugs in 5-inch pots and placed them in a 68°F (20°C) greenhouse with a 16-hour continuous photoperiod provided with high-pressure sodium (HPS) lamps (week 11).

A soft pinch was applied to each plant during week 13. Despite the diminutive size of the starting material, the plants bulked quickly in the greenhouse. Flowering occurred during week 17, 6 weeks after placement in the greenhouse.

Seed-propagated plants of gaura generally come true as well, although some variation will occur. Gaura seed does not require any special treatment for germination. Seed will sprout in approximately 5-11 days at 70°F (21°C). Seedlings can be transplanted 21-28 days after sowing. Sowing seed from February to March will generally produce flowering plants by May 1.

2. Plant Size

Juvenility has not been a factor for us in flowering *G. lindheimeri.* Plants with six leaves per shoot in 70-cell plugs flowered under 16-hour day-extension lighting. Flowering also was observed on very small vegetative cuttings while still in the plug tray.

Time to flower is similar for different sizes of starting material, although final plant size and flower number will differ. *G. lindheimeri* is best suited for finishing in a 5-inch pot when started from 128- (≤ six leaves per shoot) or 70-cell (≥ six leaves per shoot) plugs. Larger starting material may be better suited for finishing in a 1-gallon pot.

3. Cold Treatment

We recommend 6 weeks of cold at temperatures between 32°F (0°C) and 45°F (7°C) in a minimally heated greenhouse or a lighted cooler for flowering of *Gaura lindheimeri* 'Whirling Butterflies.'

Although a cold treatment is not required in order to induce flowering in *G. lindheimeri,* there are benefits of a cold treatment before exposure to LD. Without a cold treatment, we have observed that the overall flower number is low, and the plant is not sturdy.

A cold treatment slightly decreases the time to flower for gaura. Plants that did not receive a cold treatment flowered after 58 days with 16-hour day-extension lighting from HPS lamps (Figure 2a). Extending the cold treatment to 6 weeks reduced the time to flower slightly and greatly improved overall plant quality (Figure 2b). Longer cold treatments continued to decrease the time to flower minimally and increased the overall flower number.

Plugs tolerate cold exposure well if water stress is prevented. In our cooler, the plugs received 9-hour days with about 50 footcandles of light from cool-white fluorescent lamps.

4. Photoperiod

G. lindheimeri is a facultative long-day plant. Plants will bloom under short or long days, but time to flower is faster under LD. Plants grown under 13-, 14-, 16-, or 24-hour continuous photoperiods, and a 4-hour night interruption (NI), bloomed faster than plants grown under 10- and 12-hour continuous photoperiods.

Without a cold treatment and with 10-hour day-extension lighting from incandescent bulbs, flowering was observed after 75 days. Without a cold treatment and with 16-hour days, plants flowered after only 52 days. Although plants will eventually flower under 10- and 12-hour continuous photoperiods, growth is very limited, and the plants remain prostrate (Figure 3a).

After a 15-week cold treatment at 41°F (5°C), there is less of a difference (about 10 days) in time to flower between photoperiods (Figure 3b). The number of flower buds per plant was not significantly different between photoperiod treatments.

Of the plants grown with photoperiodic lighting from incandescent bulbs, those grown under 13-hour day-extension lighting with a cold treatment were of the best quality. These plants flowered after only 46 days. The plants were considerably shorter than plants grown at longer photoperiods. They had the most lateral branches, and they had a comparable flower number.

When lighting gaura with incandescent bulbs, photoperiods longer than 16 hours are not recommended because of excessive stem elongation.

Figure 2a.

Figure 2a. 72-cell rooted cuttings given no cold treatment and placed directly in a 68°F (5°C) greenhouse under a 16-hour continuous photoperiod with high-pressure sodium lamps. *Photo courtesy of Leslie Finical.*

Figure 2b.

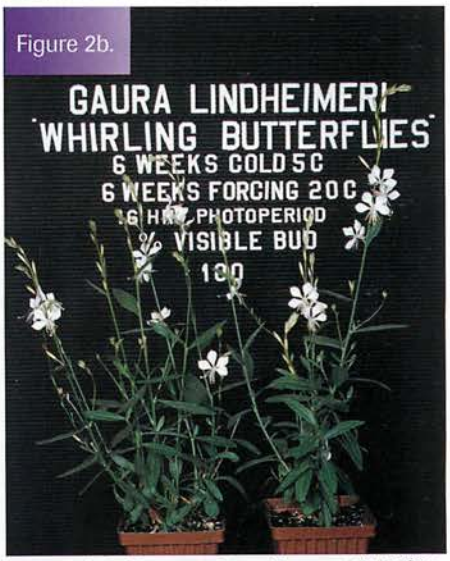

Figure 2b. Influence of cooling at 41°F (5°C) on flowering of *G. lindheimeri.* 72-cell rooted cuttings were given a 6-week cold treatment at 41°F (5°C) and then were grown in a 68°F (5°C) greenhouse under a 16-hour continuous photoperiod with high-pressure sodium lamps. Time to flower decreased, and flower number increased compared with plants not given a cold treatment (Figure 2a). *Photo courtesy of Leslie Finical.*

We recommend at least a 13-hour continuous photoperiod that is extended with either incandescent bulbs or HPS lamps.

5. Lighting And Spacing

G. lindheimeri grows best in full sun conditions and we found that supple-

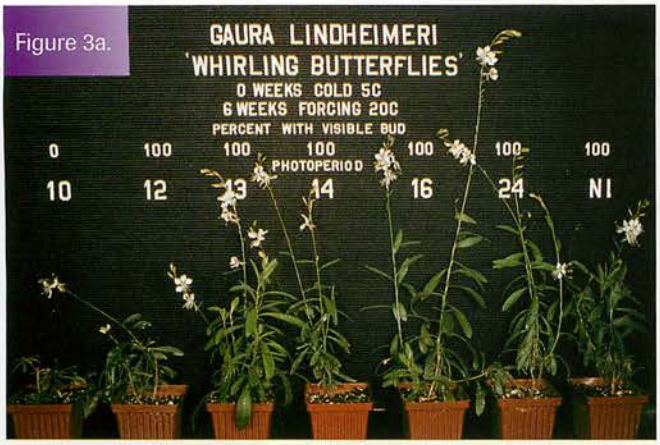

Figure 3a. Influence of different photoperiods on flowering of *G. lindheimeri*. The plants shown received no cold treatment, but instead were placed directly into a 68°F (5°C) greenhouse under seven different photoperiods. No flowering occurred on plants grown under 10-hour days. *Photo courtesy of Leslie Finical.*

Figure 3b. Influence of different photoperiods on flowering of *G. lindheimeri*. The plants shown received a 15-week cold treatment at 41°F (5°C) and then were grown in a 68°F (5°C) greenhouse under seven different photoperiods. *Photo courtesy of Leslie Finical.*

mental lighting from HPS lamps dramatically improves the quality of the crop during dark winter months. Plants grown under 16-hour continuous photoperiods with HPS lamps were of much higher quality than plants grown under the same photoperiod with incandescent bulbs (Figure 4). Using high-intensity lighting like HPS lamps to provide photoperiodic lighting generally does not decrease the time to flower. The plants shown in Figure 3 both flowered in about 47 days. There is a marked contrast, however, in the overall plant quality.

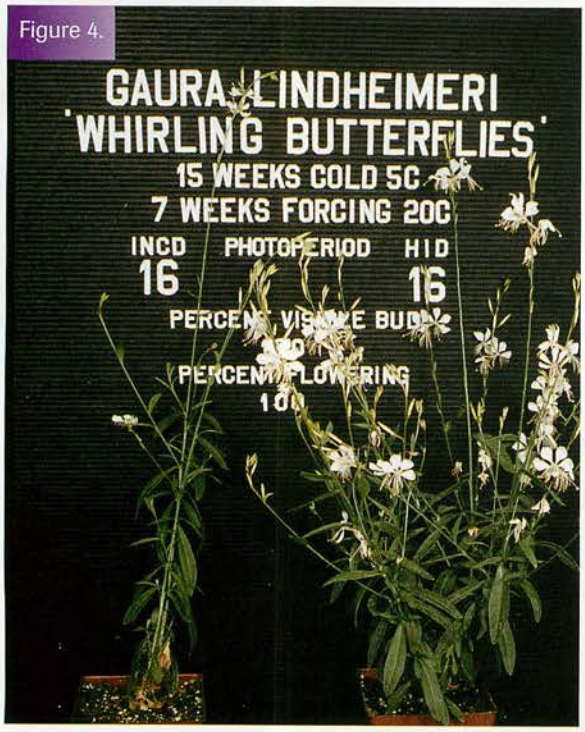

Figure 4. Influence of light quantity on flowering of *G. lindheimeri*. Plants grown under 9 hours of natural light, with 7 additional hours of light provided with incandescent bulbs, elongated excessively and produced few lateral branches. Plants grown under 16 hours of continuous light provided with high-pressure sodium lamps had increased lateral branching and flower number. *Photo courtesy of Leslie Finical.*

Incandescent lighting causes gaura to elongate excessively. Growing gaura under the shortest daylength possible, such as 13 hours, may be necessary when using incandescent lighting. The minimum light intensity for successful photoperiodic lighting is 10 footcandles.

Because gaura does not have a large spread, plants can be spaced close together. Spacing of 1-2 inches between pots, however, will help to reduce the occurrence of disease and stretching.

6. Media, Fertilization, And Irrigation

G. lindheimeri, like most gaura, is well-adapted to dry areas and well-drained soils, and it will tolerate extended drought and heat stress. It grows successfully in a wide range of soils, from dry clay to sand. Any soilless commercial media will accommodate gaura, as well. It requires average fertility and a pH of 5.8-6.5. A constant feed of 100 ppm of a 20-10-20 fertilizer is adequate for good growth.

Despite gaura's preference for well-drained soils, we observed no crown or root rot on well-watered plants during the course of this research.

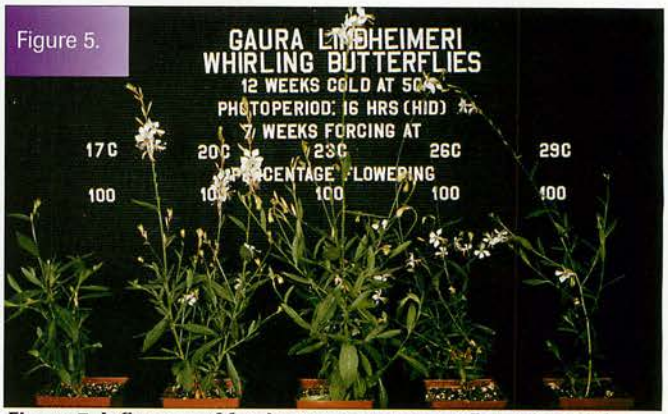

Figure 5. Influence of forcing temperature on flowering of *G. lindheimeri*. Production time from start of forcing to opening of first flower is approximately 7 weeks at 64°F (17°C), 6 weeks at 68°F (20°C), or 5 weeks at 74°F (23°C). *Photo courtesy of Leslie Finical.*

Table 1. *Gaura lindheimeri 'Whirling Butterflies' Production Schedule*

Growing time	Cultural practice	Temperature	Photoperiod
3-4 weeks	Vegetative cuttings → Root	72°-76°F (22°-24°C)	Natural daylength
	-OR- *Purchase plugs*		
6-15 weeks	Cold treatment	32°-45°F (0°-7°C)	Natural daylength or 9 hours of light in the cooler
Begin forcing **** Apply a soft pinch 2-3 weeks after start of forcing***			***≥ 13 hours of light or a 4-hour night interruption***
↓ ↓ ↓ ↓ ↓ 64°F (17°C) Flower in 50 days (7 weeks)	↓ ↓ 68°F (20°C) Flower in 42 days (6 weeks)	↓ 74°F (23°C) Flower in 35 days (5 weeks)	***Number of days from visible bud to flower*** 64°F (17°C) - 18 days 68°F (20°C) - 15 days 74°F (23°C) - 13 days

7. Plant Height Control

Because of gaura's tall nature, height control may be a concern for production. We have tested Sumagic on *G. lindheimeri* 'Whirling Butterflies' at rates of 15 and 30 ppm. The plants treated with Sumagic had received a 6-week cold treatment at 41°F (5°C) and were grown under a 16-hour continuous photoperiod with HPS lamps. Sumagic, applied at a rate of 15 ppm, was effective in reducing the final height of the plants at first flower from 48 centimeters (18.94 inches) to 32 centimeters (12.5 inches), on average.

But the reduction in height from an application of Sumagic is not permanent. Plants will eventually continue to elongate. No difference in height was observed between the 15 and 30 ppm treatments. Pinching at the start of forcing also is effective in reducing plant height and increasing lateral branching.

8. Temperatures And Crop Scheduling

Under long-day conditions, average daily temperature is the primary factor influencing flower development. Although increasing the temperature to speed up the crop may seem desirable, negative consequences may result from growing the crop too warm. Delayed flowering and reduced plant vigor and flower size can result at high temperatures.

The time to flower after beginning LD depends on forcing temperature: about 7 weeks at 64°F (17°C), 6 weeks at 68°F (20°), or 5 weeks at 74°F (23°F). Plants will flower faster at the warmer temperatures, but overall quality is highly diminished (Figure 5). During forcing, we suggest temperatures of 64°-74°F because plant and flower size are larger at cooler temperatures.

Formula For Success: 'Whirling Butterflies'

1. Seedlings or small plugs – 128s, 70s, and 50s – are appropriate for forcing in 5-inch pots. Multiple plugs are better suited for 1-gallon pots.

2. Provide plants with at least 6 weeks of cold at 41°F (5°C) before long day (LD) treatment.

3. Provide plants with LD after a cold treatment. LD can be provided by natural or extended photoperiods ≥ 13 hours or by night interruption from 10 p.m. to 2 a.m. with a minimum light intensity of 10 footcandles. Light from high-pressure sodium (HPS) lamps is preferred over incandescent.

4. Provide plants with supplemental lighting from HPS lamps during dark winter climates. Supplemental lighting at 500 footcandles will increase flower number and overall plant quality.

5. Force between 64°F and 74°F (17°-23°C).

9. Disease And Insect Pests

We observed no disease or insect pests on *G. lindheimeri* during the course of this research.

10. Postharvest Concerns

G. lindheimeri 'Whirling Butterflies' has a very long bloom time. However, removing spent flowers may encourage new flowers under well-lighted conditions. Because the plant is drought-tolerant and sturdy, the overall appearance should remain acceptable for quite some time under retail conditions. Cutting the plants all the way back to the base will result in a dense new flush of vegetative growth and plants will reflower quickly under well-lighted conditions. **GG**

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– Crop By Crop –

FORCING PERENNIALS

Species: *Geranium dalmaticum*
Common name: Dalmatian Geranium

by ***LESLIE FINICAL, ALISON FRANE, PAUL KORMAN, ARTHUR CAMERON, ROYAL D. HEINS,*** *and* ***WILL CARLSON***

Figure 1.

Figure 1. *Geranium dalmaticum* makes an excellent flowering potted plant. *Photo courtesy of Leslie Finical.*

HARDY geraniums have become very popular in recent years and have many great garden plant qualities. They are tough, versatile, and resilient, and will grow in climates ranging from USDA zones 4 to 9. They are free-flowering plants with a wide range of foliage and flower color. Perennial geraniums grow from 4 inches to 3 feet tall depending on the species.

Smaller species are excellent as dense, weed-smothering ground covers, while the taller varieties make choice accent plants in a perennial border. Some of the smaller species even exhibit potential as potted flowering plants. The leaves are deeply lobed and almost fern-like and often turn bright red in the fall. The flowers are usually 1-2 inches in diameter, and range in color from white to shades of pink and even hues of blue.

Geraniums usually prefer full sun although will tolerate partial shade. They are hardy perennials not to be confused with tender geraniums, which are actually in the genus Pelargonium. Pelargoniums do not overwinter in Northern gardens.

Hardy geraniums are members of the geranium family. The geranium family is divided into six subfamilies, which includes the genus geranium. The true geranium species, which number 456, are found in every continent of the world. About 150 geranium species are in cultivation around the world.

G. dalmaticum is a small, long-lived species native to the Balkan Peninsula which grows about 6 inches tall. *G. dalmaticum* has received England's prestigious Royal Horticulture Society's Award of Garden Merit. *G. dalmaticum* spreads rapidly by rhizomes to form a carpet of foliage, but is generally not invasive.

The leaves are very fragrant with a dark, glossy green color that turn orange and red in the fall and winter. The flowers are pale to medium pink and about 1 inch in diameter. There is also a white-flowered cultivar of *G. dal-*

maticum called 'Album.' *G. dalmaticum* is compact and tidy, and is an excellent choice for the garden and for forcing as a potted perennial.

The information provided here is for *G. dalmaticum* only. We have not conducted research on the cultivar 'Album.' *G. dalmaticum* is a facultative long day plant, which benefits from a cold treatment to shorten flowering time in the greenhouse and improve overall appearance.

1. Propagation

In the garden, *G. dalmaticum* is propagated by division in the spring or fall. Plant division helps rejuvenate old clumps, and increases or controls the number of plants. Clumps are best divided in early spring or after flowering. *G. dalmaticum* is vegetatively propagated by stem cuttings or division.

Obtaining production-quality cuttings from *G. dalmaticum* is fairly simple. We have found the best production quality cuttings can be obtained from stock plants grown under photoperiods less than 12 hours. Commercially, most growers take *G. dalmaticum* cuttings from June to July, when days are longer. We propagated a small number of plants by taking 1- to 2-inch cuttings and dipping each in a 0.1% IBA powder. The first signs of rooting were observed within 7 days.

Winter-propagated plants could respond differently to treatments, although we have not tested that possibility. The plant material we used in our experiments was commercially propagated during the months of June and July and received in October.

2. Plant Size

Juvenility has not been a factor for us in flowering *G. dalmaticum*. Plants with six leaves per shoot in 128-cell plugs flowered under 16-hour day-extension lighting.

Time to flower is similar for different size starting material, although final plant size and flower number will differ (refer to Figures 2a and 2b to note plant size and flower number differences). We also found that 128-cell plugs averaging 6-8 leaves per shoot have an average of 15 flowers per plant, whereas 70-cell plugs averaging 12 leaves per shoot have an average of 32 flowers per plant.

G. dalmaticum is best suited for finishing in a 5-inch pot when started from 70-cell (9-12 leaves per shoot) or 50-cell (12-15 leaves per shoot) plug trays. When started from 128-cell plugs, finishing in a 4-inch pot may be more appropriate. We recommend starting with plugs larger than 128s (more than eight leaves per shoot) to achieve the best end result. One plug is sufficient to fill a pot, so using multiple plugs per pot is not recommended. A finished plant will usually grow to 6 inches in height.

3. Cold Treatment

At least 6 weeks of cold at temperatures between 32°F (0°C) and 45°F (7°C) in a minimally heated greenhouse or a lighted cooler is recom-

Figure 2a. Influence of starting material size on finished *G. dalmaticum* plants. Plants were cooled at 41°F (5°C) for 6 weeks as 128-cell plugs with an average of 6-8 leaves per shoot. The plants were then grown for 9 weeks in a 68°F (20°C) greenhouse under 16-hour day-extension lighting with high pressure sodium lamps. *Photo courtesy of Leslie Finical.*

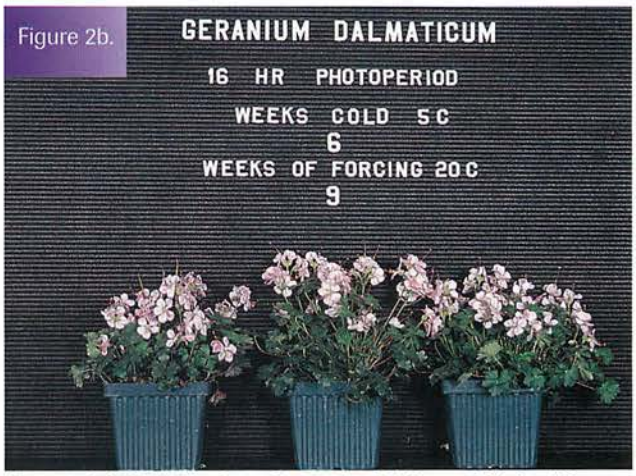

Figure 2b. Influence of starting material size on finished *G. dalmaticum* plants. Plants were cooled at 41°F (5°C) for 6 weeks as 70-cell plugs with an average of 9-12 leaves per shoot. The plants were then grown for 9 weeks in a 68°F (20°C) greenhouse under 16-hour day-extension lighting with high pressure sodium lamps. *Photo courtesy of Leslie Finical.*

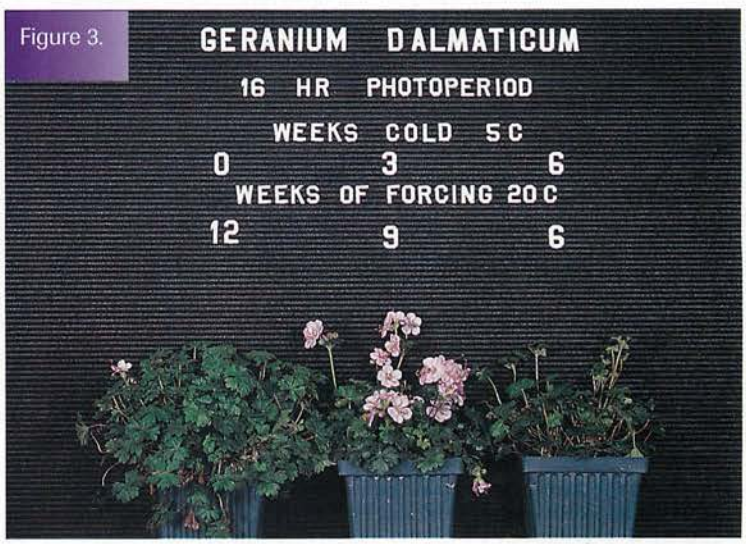

Figure 3. Influence of different durations of cooling at 41°F (5°C) on flowering time and flower number of *G. dalmaticum*. Shown are plants cooled for 0, 3, or 6 weeks, then placed in a 68°F (20°C) greenhouse under 16-hour day-extension lighting with high pressure sodium lamps. *Photo courtesy of Leslie Finical.*

mended for flower induction. Without cold, there is less than 100% flowering, flowers open on short stalks and remain obstructed by the foliage, and flower number is very low. After a cold treatment, time-to-flower decreases, flower number increases, and all plants flower (Figure 3).

Average time-to-flower decreases from 84 days without cold, to an average of about 50 days after 6 weeks of cold. Longer cold treatments will continue to decrease the time to flower only slightly (Figure 4). To a botanist, *G. dalmaticum* would be categorized as "cold-beneficial." To a horticulturist, *G. dalmaticum* requires a cold treatment.

Plugs tolerate exposure to cold well if water stress is prevented. In our cooler the plugs received 9-hour days with about 50 footcandles of light from cool-white fluorescent lamps. Plugs were stored for 20 weeks in our coolers with no deleterious effects observed.

4. Photoperiod

G. dalmaticum is a facultative long-day plant after cold treatment. Plants will bloom under short or long days but time to flower is quicker under long days. Plants grown under 16- and 24-hour photoperiods, and a 4-hour night interruption (NI), bloomed faster than plants grown under 10-, 12-, 13-, and 14-hour day-extension lighting. Without a cold treatment, no flowering was observed under any photoperiod that was extended with incandescent bulbs.

After a 15-week cold treatment at 41°F (5°C), the most rapid and uniform flowering occurred under 16-hour day-extension lighting and NI lighting. The number of flower buds per plant is not affected by photoperiod. We recommend 16-hour day-extension lighting or 4-hour NI for *G. dalmaticum*.

Figure 4.

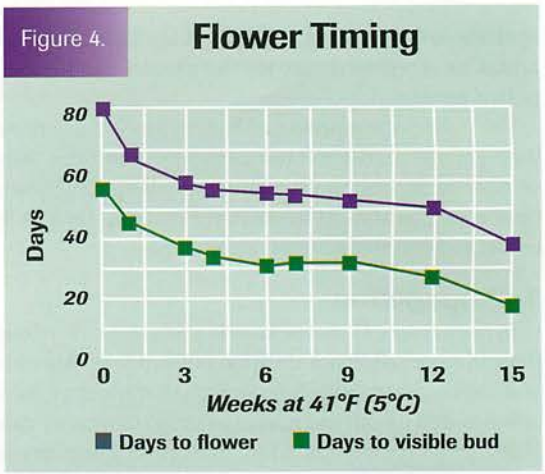

Figure 4. Influence of long durations of cooling at 41°F (5°C) on flowering of *G. dalmaticum*. Time to flower decreases only slightly after long durations of cold. Plants were grown in a 68°F (20°C) greenhouse under 16-hour day-extension lighting with high pressure sodium lamps. *Graphic courtesy of Leslie Finical.*

5. Lighting And Spacing

G. dalmaticum grows best in full sun conditions but will tolerate partial shade in the garden. Supplemental lighting from high pressure sodium (HPS) lamps will improve the crop quality during dark winter months. Plants that received no cold treatment failed to flower when grown with 16-hour day-extension lighting with incandescent bulbs. Plants that received no cold treatment and were grown under 16-hour day-extension lighting with HPS lamps achieved 30%-75% flowering.

Using high intensity lighting, such as HPS lamps, to provide photoperiodic lighting may decrease the time to flower and improve the overall quality of the crop. 70-cell plugs given a 15-week cold treatment at 41°F (5°C) and then grown in a 68°F (20°C) greenhouse under 16-hour day-extension lighting from HPS lamps flowered in an average of 45 days. 52-cell plugs given the same cold treatment, then placed in the greenhouse under 16-hour day-extension lighting from incandescent bulbs, flowered in an average of 54 days. The minimum light intensity for successful photoperiodic lighting is 10 footcandles.

Because the plants are compact, spacing can be fairly close. Spacing of about 1-2 inches between pots will help to minimize the occurrence of disease and

Figure 5.

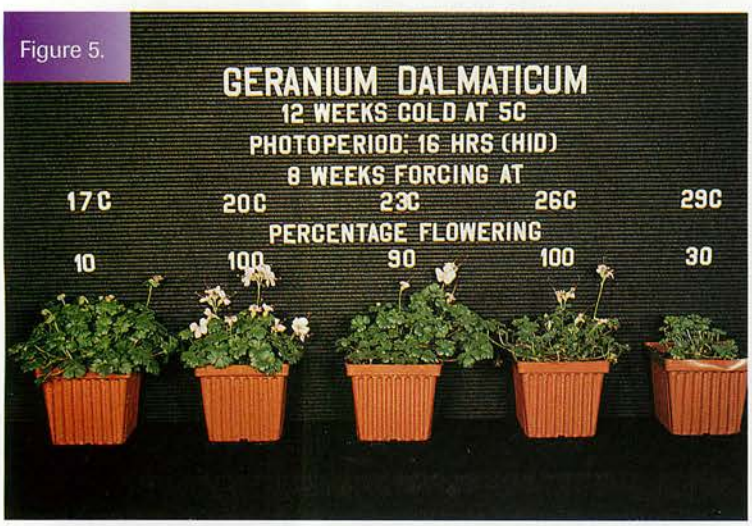

Figure 5. Influence of forcing temperature on flowering of *G. dalmaticum*. Production time from start of forcing to opening of first flower is approximately 8 weeks at 64°F (17°C), 7 weeks at 68°F (20°C), or 6 weeks at 74°F (23°C). *Photo courtesy of Alison Frane.*

Figure 6.

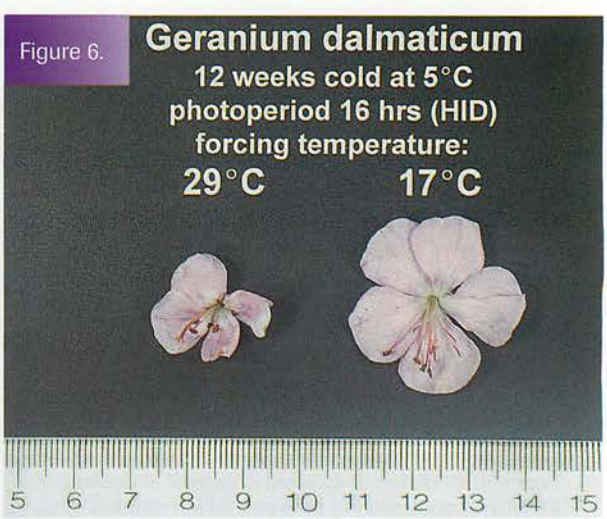

Figure 6. Influence of forcing temperature on flower size of *G. dalmaticum*. Flower size increases dramatically at cooler temperatures (64°F and 84°F). *Photo courtesy of Alison Frane.*

Table 1. **Geranium dalmaticum Production Schedule**

Growing time	Cultural practice	Temperature	Photoperiod
3-4 weeks	Vegetative cuttings	72°-76°F (22°-24°C)	Natural daylength
4-5 weeks (128-cell plug) Longer for larger	Bulk or pinch to increase vegetative growth of plugs	68°-72°F (20°-22°C)	Natural daylength
	-OR- *Purchase plugs*		
6-15 weeks	Cold treatment	32°-45°F (0°-7°C)	Natural daylength or 9 hours of light in the cooler
	Begin forcing		***≥16 hours of light or a 4-hour night interruption***
↓ ↓ ↓ ↓ ↓ ↓ 64°F (17°C) Flower in a average of 59 days (8 weeks)	↓ ↓ 68°F (20°C) Flower in a average of 49 days (7 weeks)	↓ 74°F (23°C) Flower in a average of 41 days (6 weeks)	***Number of days from visible bud to flower*** 64°F (17°C) - 29 days 68°F (20°C) - 23 days 74°F (23°C) - 18 days

6. Media, Fertilization, And Irrigation

G. dalmaticum, like most hardy geraniums, is well adapted to dry areas and well-drained soils and will tolerate extended drought stress. *G. dalmaticum* grows best in a well-drained, bark-based media with a pH between 6.0 and 6.5. A constant feed of 100 ppm of a 20-10-20 fertilizer is adequate for good growth.

Although *G. dalmaticum* should not be overwatered, no incidents of crown or root rot were observed on well-watered plants.

7. Plant Height Control

Because *G. dalmaticum* grows to only 6 inches, no height control is necessary.

8. Temperatures And Crop Scheduling

Under long-day conditions, average daily temperature is the primary factor influencing flower development. The time to flower of *G. dalmaticum* was about 8 weeks at 64°F (17°C), 7 weeks at 68°F (20°C), or 6 weeks at 74°F (23°C). Plants will flower faster at the warmer temperatures up to 78°F (26°C) (Figure 5).

Although increasing the temperature to speed up the crop may seem desirable, there are negative consequences that result from growing the crop too warm. *G. dalmaticum* will experience heat delay of flowering at temperatures of 78°F (26°C) or above (Figure 5). During forcing, we suggest temperatures of 64°-74°F because plant and flower size are larger at cooler temperatures (Figure 6).

Formula For Success: Dalmatian Geranium

1. Use larger plugs for superior quality plants – 70 50-cell plugs with more than nine leaves per shoot are appropriate for 5-inch pots.

2. Provide plants with at least 6 weeks of cold temperature between 32°F (0°C) and 45°F (7°C) before long day (LD) treatment.

3. Provide plants with long days after the cold treatment. LD can be provided by natural or extended photoperiods of 16 hours or by night interruption from 10 p.m. to 2 a.m. with a minimum light intensity of 10 footcandles.

4. Force between 64°F and 74°F (17°C and 23°C) for best quality.

5. Provide plants with supplemental lighting from high pressure sodium lamps during the dark winter months. Supplemental lighting increases flower number and overall plant quality.

9. Disease And Insect Pests

No disease or insect pests were observed on *G. dalmaticum* during the course of this research.

10. Postharvest Concerns

G. dalmaticum will hold the initial flush of flowers for approximately 2-3 weeks, beyond which new flowers will continue to emerge sparsely. Because flowers are small, their immediate removal upon finishing is not necessary.

However, removing spent flowers may encourage new flowers under well-lit conditions. Because the plant is fairly drought-tolerant and sturdy, the overall appearance should remain acceptable for quite some time under retail conditions. Cutting the plants all the way back to the base will result in a quick new flush of vegetative growth but with limited flowering. **GG**

– Crop By Crop –

FORCING PERENNIALS

Species: *Hibiscus moscheutos* 'Disco Belle Mixed'
Common name: Swamp Rose Mallow

Figure 1.

Figure 1. The flower of *Hibiscus* 'Disco Belle Mixed' attracts the most attention. This five-petalled corolla can be white (left), pink, red, rose-colored (right), or bi-colored and typically has a crimson center or eye.

by ***SHI-YING WANG, ROYAL D. HEINS, WILL CARLSON,*** *and* ***ARTHUR CAMERON***

HIBISCUS moscheutos is one of the northern-most members of the largely tropical and subtropical family Malvaceae. It is a marshland native of the eastern U.S. The robust exotic appearance of the variety make it a plant of merit.

The large flat or shallow to sharply cupped flowers are up to 12 inches (30 centimeters) across, and borne solitarily in the axils of leaves. The five-petalled corolla can be white, pink, red, rose-colored, or bi-colored and typically has a crimson center or eye (Figure 1).

Plant height ranges from 20 to 60 inches (50-150 centimeters). It is hardy from USDA zones 4 to 9. In the Great Lakes area, flowering begins approximately the first week of August and continues until frost or flower initiation ceases due to shortening days of fall.

Many cultivars currently on the market are horticultural hybrids between *H. moscheutos* and other Hibiscus species, but are often listed as cultivars of *H. moscheutos*. The most common cultivars are 'Disco Mixed Belle,' ' Lady Baltimore,' and 'Lord Baltimore.'

There are other cultivars available, such as 'Anne Arundel,' 'Blue River II,' 'Crimson Wonder,' 'Fleming Hybrids,' 'George Riegel,' 'Giant Maroon,' 'Lester Riegel,' 'Southern Belle,' 'Strawberry Swirl,' and 'Sweet Caroline.' All suggested production information in this article is based on observed responses of *H. moscheutos* 'Disco Belle Mixed' (Figure 2).

1. Propagation

H. moscheutos can be propagated by cuttings, division, and seed. One of the merits of 'Disco Belle Mixed' is that it is easily propagated from seed. Plugs are typically produced at 70°-75°F (21°-24°C). Common plug sizes include 128-cell trays and 338-cell trays transplanted into 55-cell trays.

2. Plant Size

Juvenility is not a major consideration for flowering. Seedlings with as few as 4-5 leaves can be forced to flower. In order to promote branching, plants should be pinched at 4-6 leaves. A finished plant can grow as tall as 30 inches (75 centimeters). The plant is best suited for 6-inch or 1-gallon pots. Three plants can be forced in one pot (Figure 3); these pots are more attractive when flower colors of those three plants are different.

3. Cold Treatment

Plants go dormant in early fall under natural growing conditions. Although mature bare-root crowns can be stored at low temperatures, a young seedling (4-9 leaves) is difficult to hold at 5°C. Exposure to low temperature causes death of the leaves and stems. Plants may also die from extended cold storage if water stressed or overwatered (Figure 4). Because of these problems, cold storage of Hibiscus plug seedlings is not recommended. Instead, plants should be seeded, germinated, and then transplanted to the finished containers at warm temperatures.

4. Photoperiod

'Disco Belle Mixed' is an obligate long-day plant. Under photoperiods of 10 hours or less, plants remain vegetative. All plants can be rapidly induced to flower when the photoperiod exceeds 14 hours; flowering is fastest when photoperiod is 16 hours and above (Figure 5). Therefore, plants should be forcing under a 16-hour or longer photoperiod, or under natural days plus a 4-hour night interruption (2200 to 0200 HR).

Figure 3. *Hibiscus* 'Disco Belle Mixed' is very versatile and three plants per pot make it more attractive. However, plants can become cholorotic and even suffer leaf drop when grown at cooler temperatures and overwatered (plant on right). *Photo courtesy of Catherine Whitman.*

5. Media, Fertilization, And Irrigation

H. moscheutos is also called the swamp rose mallow because it loves wet areas and requires a sufficient supply of water. Consistent soil moisture is important and plants should not be allowed to dry out. However, they need not be planted in a swampy area. Plants grow best in moist soil with a high organic content, but they tolerate a wide range of moisture conditions. Plants may develop leaf chlorosis, especially when ghrowing under cooler temperatures.

Figure 5.

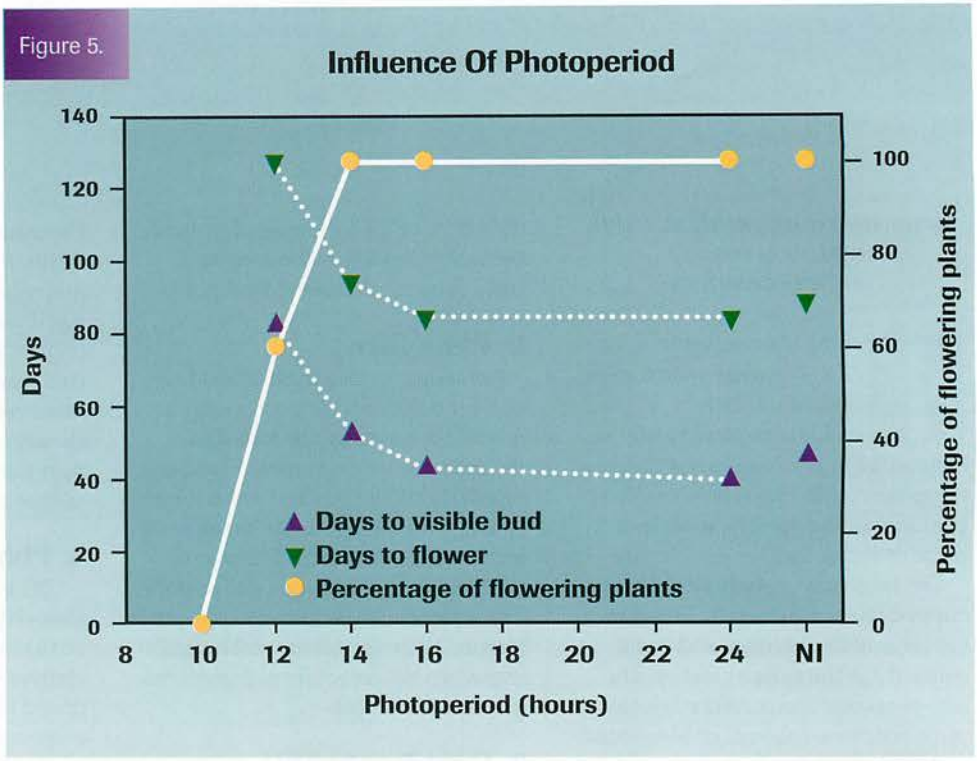

Figure 5. Influence of photoperiod on percentage of flowering plants, days to visible bud, and days to flower in *Hibiscus* 'Disco Belle Mixed.' NI stands for night interruption. *Data was adapted from Erik S. Runkle.*

6. Lighting And Spacing

Plants grow best in full sun, but they also tolerate partial shade. Heavy shade will result in tall plants with few flowers. Plants can be grown in groups of 3-5 in full sun for best effect.

7. Plant Height Control

Both chlormequat (Cycocel, 1000 ppm) and uniconazole (Sumagic, 15 ppm) are effective chemicals for height control. Multiple applications are probably necessary.

8. Temperatures And Crop Scheduling

Under long-day conditions, average daily temperature is the primary factor influencing flower development; increasing temperature decreases time to flower (Figure 6). Plants often become chlorotic when grown at or below 68°F (20°C). If this problem occurs, plants can be transferred to a warm temperature environment to overcome this chlorosis. Warm temperatures (75°F and above) are recom-

Figure 4.

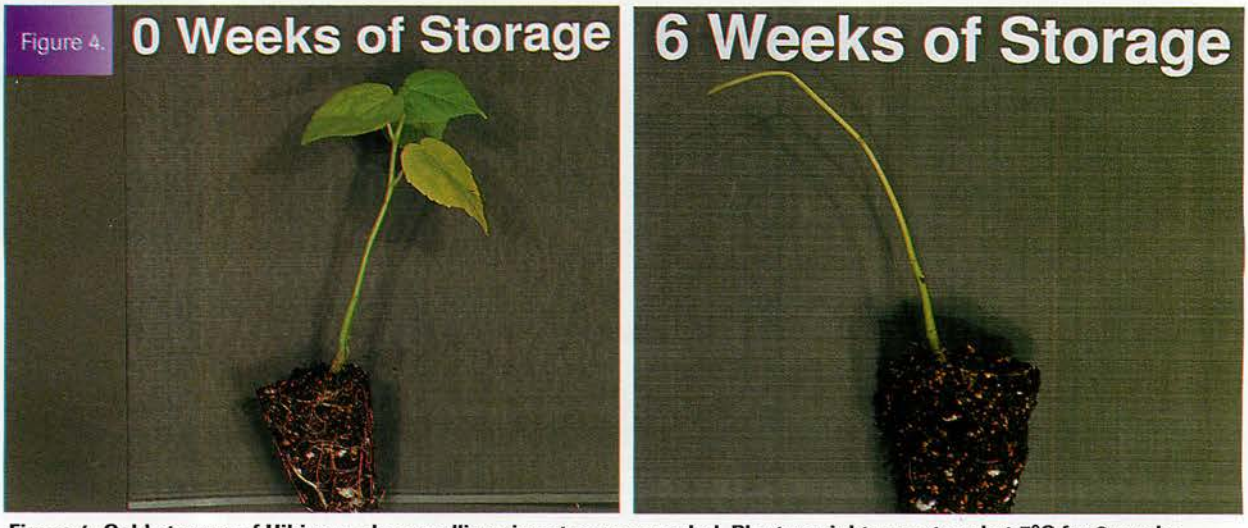

Figure 4. Cold storage of Hibiscus plug seedlings is not recommended. Plant on right was stored at 5°C for 6 weeks.

Table 1. ***Hibiscus moscheutos 'Disco Belle Mixed' Production Schedule***

Growing time	Cultural practice	Temperature	Photoperiod
5-7 weeks	Sow seeds Germination OR purchase plugs	70°-76°F (21°-24°C)	Natural light
	Begin forcing (at 4-9 leaves)		
↓↓↓↓↓↓↓↓ 68°F (20°C) 14 weeks flower (not recommended)	↓↓↓ 75°F (23°C) 9 weeks flower	↓↓ 79°F (26°C) 8 weeks flower	↓ 84°F (29°C) 7 weeks flower
			16 hours of light or 4-hour night interruption

Visible bud to flower
68°F (20°C) - 52 days
75°F (23°C) -38 days
79° (26°C) - 32 days
84°F (29°C) - 28 days

mended for forcing 'Disco Belle Mixed.' Time to opening of the first flower after the onset of long days averages 9-12 weeks at 68°F (20°C), 8-9 weeks at 75°F (24°C), and 7 weeks at 81°F (27°C).

9. Disease And Insect Pests

Whiteflies can be a problem in the greenhouse and Japanese beetles can be devastating in the garden.

10. Postharvest Concerns

Each blossom lasts only 1 day.

Figure 6.

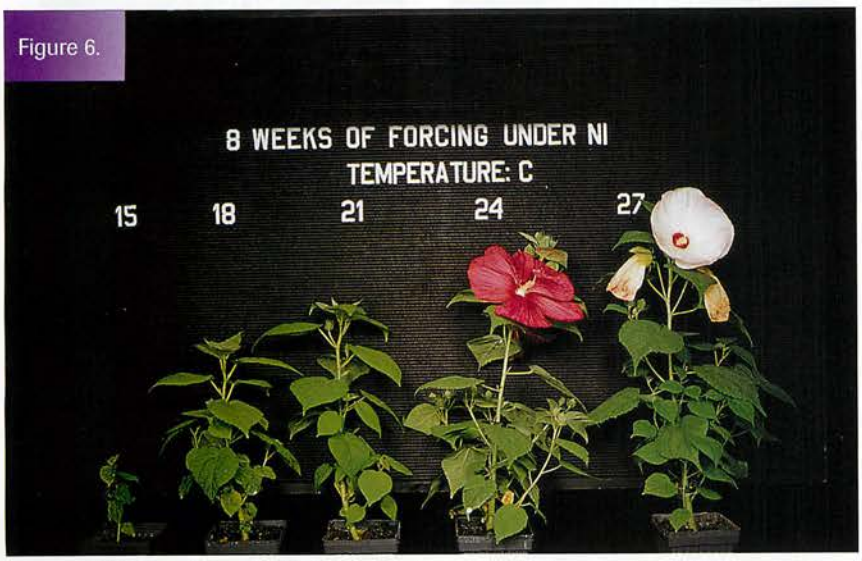

Figure 6. *Hibiscus* 'Disco Belle Mixed' thrives in warm temperatures. These plants were forced under a 4-hour night interruption. Plants at treatments of 75°F and 81°F (24°C and 27°C) have flowered.

Formula For Success: 'Disco Bell Mixed'

1. Do not hold plugs at low temperatures (>50°F).
2. Force plants at warm temperatures (>75°F).
3. Provide long photoperiods (>16-hour or 4-hour night break).
4. Apply growth retardant to keep plants short.

Wilting petals may be handpicked or allowed to fall naturally. The plant's aesthetic appearance benefits from prompt removal of spent flowers. **GG**

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FORCING PERENNIALS

– Crop By Crop –

Species: *Hosta* spp.
Common Name: Hosta, Plantain Lily

Figure 2a, 2b. Plant size influences growth and flowering of *Hosta.* Single-eye divisions yield small plants with low flowering percentages (left), while multiple-eye divisions yield larger, more vigorous plants with higher flowering percentages (right).

Figure 1. Hostas thrive in shade gardens.

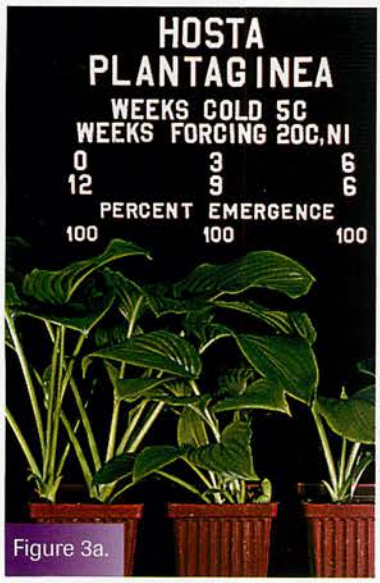

Figure 3a. All *Hosta plantaginea* plants emerged when grown at 68°F (20°C) without a cold treatment.

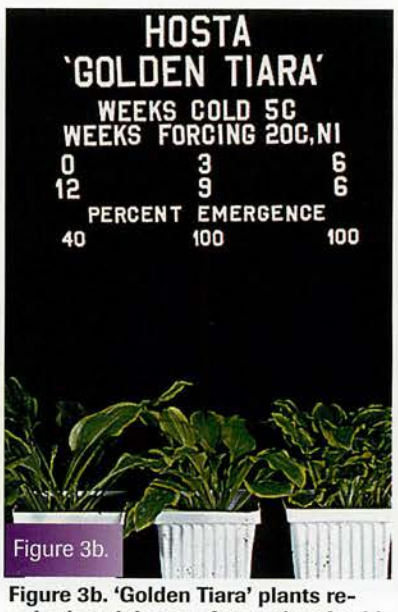

Figure 3b. 'Golden Tiara' plants required a minimum of 3 weeks of cold at 41°F (5°C) for all plants to emerge from dormancy.

Figure 3c. 'Tokudama' gold plants required a minimum of 6 weeks of cold at 41°F (5°C) for all plants to emerge from dormancy.

Table 1. **Forcing Comparisons for *Hosta***

Cultivar	Weeks of cold at 41°F (5°C) required for 100% emergence	Required photoperiod for continual growth and flowering	Plant responses at recommended forcing temperatures					
			°F (°C)	Days to emerge	Weeks to visible bud	Weeks to flower	Foliage height in. (cm)	Inflorescence height at anthesis in. (cm)
'Lancifolia'	0	≥14 hours or NI	64-75 (18-24)	4-7	9-11	12-15	6 (16)	18-22 (45-55)
plantaginea			70-79 (21-26)	3-4	9-12	12-14	10-12 (25-30)	16-18 (40-45)
'Royal Standard'				11-14	11-12	14-16	8-10 (20-25)	26 (65)
'Francee'	2-4[a]	≥14 hours or NI[b]	64-75 (18-24)	9-14	7-10	10-13	8-10 (20-25)	20-24 (50-60)
'Golden Scepter'	3	≥13 hours or NI	64-75 (18-24)	4-5	7-9	10-12	6-7 (15-18)	14-15 (35-38)
'Golden Tiara'				6-7	5-6	8-10	5-6 (12-15)	18-20 (45-50)
'Fortunei Hyacinthina'				9-13	7-10	10-13	10-12 (25-30)	24-26 (60-65)
'Undulata Variegata'		≥14 hours or NI		7	6-7	10-12	6-8 (15-20)	26-30 (65-75)
montana			61-70 (16-21)	4-5	4-9	9-14	7-8 (18-20)	20-28 (50-70)
'Tokudama' gold	6	≥14 hours or NI	61-70 (16-21)	10-15	5-8	8-12	3-4 (8-10)	12-14 (30-35)
'Tokudama' green				11-15	5-8	10-12	4-7 (10-18)	12-16 (30-40)

[a] G.J. Keever, M.S. West, and R. Kessler, Jr. 1999. Chilling effects on shoot emergence and subsequent growth in Hosta. J. Environ. Hort 17(2):84-87.
[b] L. Finical, A. Cameron, R. Heins, W. Carlson, and C. Whitman. 1997. Influence of cold treatment and photoperiod on development and flowering of *Hosta*. The Hosta Journal 28(2):88-89.

by ***BETH FAUSEY, ARTHUR CAMERON, ROYAL HEINS,*** *and* ***WILL CARLSON***

HOSTA shoots emerge in the spring to unfold a lush display of foliage in myriad color combinations. Hostas have long been the perennial plants of choice for shade gardens where few other ornamentals thrive (Figure 1). But these popular perennials are no longer solely delegated to the dense shade of woodland gardens because cultivars suitable for partial and full sun exposure are now widely available.

Collectively, hostas are the best-selling herbaceous perennials. Their immense popularity is largely due to their versatility and adaptability. Culturally, hostas thrive in various degrees of sun and shade, tolerate variable soil moisture levels, require minimal care, and endure vast climatological differences.

Hostas are native to China, Japan, and Korea, and were brought to the U.S. in the early to mid-1800s. They are well adapted to the North-American climate and are hardy across much of the continental U.S., from USDA hardiness zones 3 to 8.

These plants are enormously diverse in form, growth habit, and cultural requirements. Similarities in growth habit and flower structure often led taxonomists to classify them with Hemerocallis in Liliaceae.

More recently, hostas have been classified in a distinct family, the Hostaceae. The genus has been divided into approximately 40 species and more than 2000 named cultivars, with

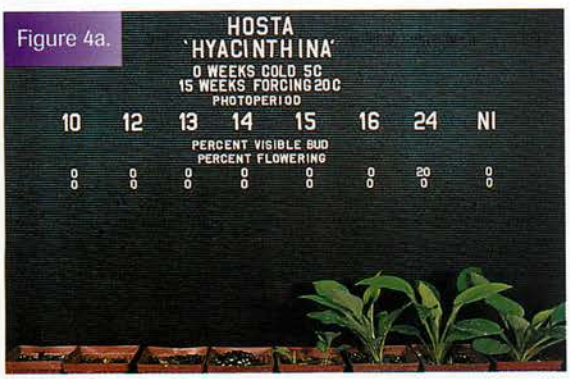

Figure 4a. Emergence percentages were low under all photoperiods for uncooled plants of cold-requiring hostas such as 'Hyacinthina.' Vigor and flowering percentages were low for the plants that did emerge.

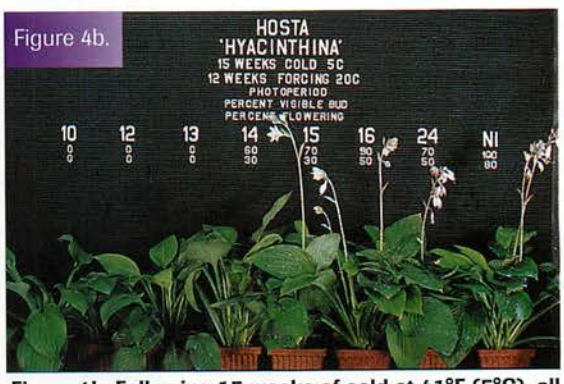

Figure 4b. Following 15 weeks of cold at 41°F (5°C), all 'Hyacinthina' plants emerged regardless of photoperiod treatment. Only plants grown under photoperiods >14 hours continually produced new leaves and flowered while plants grown under photoperiods <13 hours entered a vegetatively dormant state.

new introductions annually. Many plants that were once considered true species are now considered cultivars originating in gardens or through hybridization in the wild.

Hostas traditionally have been grown exclusively for their ornamental foliage. However, flowers are important when hostas are forced for sale or show, crossed with plants that have incongruent flowering times, or are propagated.

Our guide to forcing is based on the responses of nine cultivars and two species – only a small representation of the diversity within Hosta – to experimental conditions in our research program (Table 1).

1. Propagation

Hostas can be sexually or asexually propagated. Most plants hybridize readily and produce many viable seeds in each seed capsule. Seed propagation is reserved for breeding because all hostas, except *Hosta ventricosa*, do not come true from seed.

Asexual propagation methods must be used to retain the distinctive characteristics of each hosta, such as leaf shape, size, color, and substance. All vegetatively propagated hostas are genetically identical clones originating from a single individual.

Hosta clones can be produced in large quantities from tissue culture or division. Division involves removing a section of the crown tissue containing at least one bud and several associated roots, and is usually performed in the spring or fall. Buds that form on the hosta crown can be terminal or lateral.

A terminal bud is a large, central bud formed on plants that do not flower during the growing season. A large, central shoot will emerge from divisions with a single terminal bud.

Lateral buds develop in each leaf axil, where the leaf is attached to the crown, and potentially form new shoots. When the hosta's growing point is removed and the plant flowers, growth of the original shoot ceases and new, smaller shoots emerge from the lateral buds.

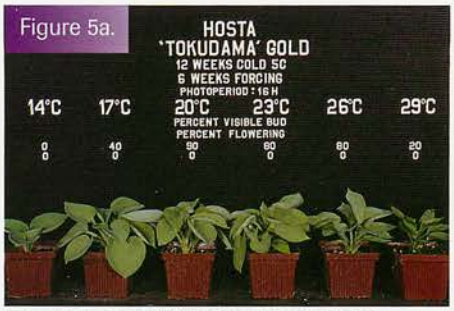

Figure 5a. Production time to force *Hosta* 'Tokudama' plants for foliage is 4 weeks at 74°F, 6 weeks at 64°-68°F, and 8 weeks at 58°F.

Figure 5b. The detrimental effects of temperatures above 80°F are apparent on *Hosta* 'Tokudama' gold plants following 12 weeks of forcing.

Figure 6. Influence of forcing temperature on leaf size, shape, and color of *Hosta* 'Francee' grown from 58°F to 84°F (14°-29°C) for 15 weeks.

Formula For Success: Hosta

1. Begin with large, mature divisions for sizeable plants.

2. Provide 6 weeks of cold at 32°-41°F (3°-5°C) for complete emergence and vigorous growth.

3. Force hostas under photoperiods >14 hours to prevent plants from going dormant and promote continual growth and flowering when the natural daylength is less than 14 hours.

4. Grow plants at or below 74°F (23°C) to optimize the appearance of the foliage and flowers.

5. Avoid water stress.

Growth of lateral and latent buds formed on the hosta crown can be initiated following applications of benzyladenine, a cytokinin. The amount of benzyladenine needed for shoot development varies with concentration, chemical formulation, and application method. The number of offshoots produced on a single hosta division following application depends on the cultivar.

2. Rooting

Commercial producers harvest most bare-root hostas in late summer or early fall. They are cooled during storage, shipped to growers the following spring, and forced for sale. Bare-root hostas generally root slowly after planting. Plants from bare-root divisions may have a full foliage canopy and appear ready for sale but sometimes can be pulled out of the container easily.

More growing time is needed to improve rooting of newly planted divisions. Rooting of divisions planted in the summer or early fall is not as problematic because plants become established in containers and are overwintered before forcing in the spring.

3. Plant Size

Crown maturity and plant size influence growth and flowering of *Hosta*. In our experiments, small, single-eye divisions developed into small plants with low flowering percentages (Figure 2a). When we bulked these same plants outside under 50% shade for 5 summer months, the hostas developed into larger, more uniform plants with higher flowering percentages (Figure 2b). For example, the flowering percentages for 'Golden Scepter' and 'Golden Tiara' increased from 20% and 40%, respectively, in their first year to 100% in their second year.

Although flowering is not a goal for most growers, starting crown size will influence foliage size. Incidentally, most cultivars require multiple growing points to fill a 5-inch or larger pot.

4. Cold Treatment

Hostas naturally become dormant in the fall as the daylength shortens, and most require a cold treatment to reinitiate growth. The amount of cold needed for growth depends on the cultivar. All cultivars we tested re-

quired 6 weeks or less of cold at 41°F (5°C) to break vegetative dormancy (Table 1). Not all plants of each cultivar emerged when given an inadequate cold treatment.

Cold was not required for flowering of Hosta. A cold treatment generally reduces time to flower and improves flowering uniformity, overall vigor, and plant quality. We suggest a 6-week cold treatment for all Hosta, unless the specific cold requirement is known.

Hosta plantaginea 'Royal Standard' and 'Lancifolia' did not require a cold treatment (Figure 3a). *Hosta plantaginea's* native habitat is in the warm, humid climate of southern China (25°-30° N latitude). 'Royal Standard' is a seedling of *H. plantaginea*, while the origin of 'Lancifolia' is unknown. The parental species of several hostas that required cold temperatures for complete emergence are native to Korea and Japan (35°-45° N latitude), areas that receive periods of cold temperatures (Figures 3b and 3c).

5. Photoperiod

Hostas are obligate long-day plants for continued leaf formation and flowering. Following cold, plants produce an initial flush of leaves when grown under short-day photoperiods and then enter a vegetatively dormant state (Figure 4a). Plants of all cultivars we tested actively produced new leaves and flowered only when the daylength exceeded 13 or 14 hours (Figure 4b). We recommend growing hostas under photoperiods greater than 14 hours or with a 4-hour night interruption when the natural daylength is less than 14 hours, unless dormancy is desired.

The natural daylength varies with latitude and is approximately 14 hours or less from September 4 to April 8 at 42° N latitude (East Lansing, MI) and from August 24 to April 19 at 33° N latitude (Atlanta, GA). Extending the daylength or providing night-interruption lighting requires 10 footcandles of light from incandescent or high-pressure sodium lamps.

Long-day photoperiods will promote an increase in the number of shoots per pot, effectively bulking the crown if plants flower. The number of new shoots depends on the cultivar.

6. Media, Fertilization, And Irrigation

All plants performed well in our experiments when grown at a pH of 5.8-6.2 with moderate fertility levels of 100-150 ppm N, 10-20 ppm P, and 100-150 ppm K delivered at each watering. Hostas required adequate moisture levels and developed marginal leaf burn when they were drought stressed.

Marginal leaf necrosis was noticeable on newly divided plants with poorly developed root systems. Necrosis on small plants was exacerbated under intense light and high temperature.

Marginal leaf burn was not common on plants growing in a pot for many months, with fully developed root systems. Marginal leaf burn detracts from the quality of the foliage and may render plants unsalable until a new flush of leaves develops.

7. Lighting And Spacing

Hostas look best when they are grown in partial shade. Plants will survive full sun in northern climates, but the foliage may bleach and marginal necrosis may develop. To avoid bleaching and necrosis, grow plants under light levels of 5000 footcandles or less in the greenhouse. Plants can be grown pot to pot for several weeks after emergence. Wider spacing may be needed for large-leaved cultivars.

8. Plant Height Control

Height control of hosta foliage is generally not an issue. Dwarf and smaller cultivars can be selected when plant height is a concern.

Flower stalks can be very tall, making height control more problematic. We have not examined using growth retardants to control foliage or flower stalk height.

9. Temperatures And Crop Scheduling

Cool temperatures maximize the appearance of hosta foliage and flowers. Flower and leaf color is more intense between 58° and 74°F (14°-23°C) than at warmer temperatures (Figure 5a). The foliage of gold, blue, and variegated cultivars lost their characteristic colors and became green when plants were grown at 84°F (29°C) (Figure 5b).

Hostas grown at average daily temperatures greater than 80°F exhibit a rosette growth habit. Leaves lose distinctive cultivar-specific characteristics, such as a decrease in leaf size, a narrowing of the leaf blade, and a change in color (Figure 6).

Hostas emerge in response to the root-zone temperature irrespective of photoperiod. Plants will emerge in 1-2 weeks at 64°-79°F (17°-23°C), depending on the cultivar. Cooled plants forced for foliage alone will be ready for sale in 4-6 weeks at 68°-74°F (20°-23°C) and 6-8 weeks at 58°-64°F (14°-17°C). Flower development of most cultivars was fastest at 74°F, with one exception. Flowering of *H. plantaginea* was quickest at 78°F. Time to flower varies with cultivar and can range from 8 to 16 weeks at 74°F. The range of temperatures and the time to flower for each cultivar are presented in Table 1.

10. Disease And Insect Pests

Slugs are the most destructive pest of hosta and were the only pest in the greenhouse. They are easily inadvertently shipped with plant material, which should be inspected upon arrival. Metaldehyde and methiocarb effectively control slugs.

Rhizoctonia root rot was a problem for some newly planted divisions in our experiments. A broad-spectrum fungicidal drench is suggested following planting of newly divided single-eye divisions.

11. Postharvest Concerns

Postharvest of flowers is generally not a concern since most hostas are grown for their foliage, although many cultivars have scented or attractive flowers. Flowers open in sequence from the bottom, lasting 1-3 weeks, depending on the number of flower buds formed.

Spent flowers and flower stalks distract from plant quality and should be removed following flowering. Plants should not be marketed in full sun or be severely water stressed because foliar necrosis likely will develop. **GG**

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