Horticulture Section

School of Integrative Plant Science

Cut flower research summaries

H. C. Wien, emeritus professor, Cornell University

Studies on the production of cut flowers were conducted at Cornell University from 2004 to 2015 and summarized yearly (available at flowerbulbs.cornell.edu/cutflowers). Although a few might be interested in the details of this work, most would likely only want broad summaries of these topics, and so this is an attempt to provide that information.

Contents

1. Sunflower daylength response

Sunflowers grown for cut flowers in temperate climates are generally either started in greenhouses or direct-seeded in the field after danger of frost is past. Those wishing to have an early crop may sow the seed during a time when the daylength is 12 hours or shorter (earlier than middle of March in Washington DC, or 39 N). If so, growers need to be aware of the reaction of those varieties to the daylength that exists during the 3 weeks after the seedlings emerge. During those first 3 weeks that the young plants can perceive the daily duration of light, some varieties show no reaction, while many others switch from producing leaves to starting to produce flowers at the growing point. Those switching to flower production in the relatively short days of early spring are called short-day varieties; those showing no reaction are termed day-neutral. There are even a few varieties that react in the opposite way: they are delayed in flowering under short-day conditions and are called long-day varieties.

What difference does the reaction to length of day make to growth of cut sunflowers? When the variety is stimulated to switch to producing flowers early, fewer leaves are formed, the ultimate height of the plant is smaller, and the flowers will be smaller in diameter. Although the earlier flowering time is welcome, the smaller plants also tend to produce more than one flower bud at the top, and also additional buds in the leaf axles (Fig. 1).

Fig. 1 'Premier Light Yellow' sunflower grown at 12 h (left) or 16 h daylength in 2006.

If these features are objectionable, growers should grow only day-neutral varieties. In the tables below, we tested 76 varieties for daylength reaction in trials from 2006 to 2015. For varieties that have come out since then, growers may need to run their own simple experiments. If starting new varieties early in a greenhouse, divide the seedlings into two groups, one that receives 16 hours light by placing a string of artificial light over the bench, and the other on another bench exposed to only the natural length of day of the season. Both groups can then be planted out into the field as normal, and the differences in plant appearance and flowering time observed.

Table 1. The reaction of sunflower varieties grown as cut flowers to the length of the day. Trials conducted from 2006 to 2015. Varieties are shown in alphabetical order.

VARIETY	TIME OF FLOWERING		SENSITIVITY CLASS
	SHORT DAY	LONG DAY	
Apricot Daisy	68	64	DN
Big Smile	54	63	SD
Buttercream	66	63	DN
Chianti	62	68	DN
Coconut Ice	64	58	DN
Dafne	53	73	SD
Double Quick Orange	84	73	LD
Florenza	64	65	DN
Frilly	78	67	LD
Full Sun Improved	69	72	DN

Giant Sungold	99	97	DN
Goldrush	58	66	SD
Goldy Double	89	89	DN
Helios Flame	55	64	SD
Jade	66	60	DN
Jua Inca	56	62	DN
Jua Maya	56	60	DN
Moonbright	60	75	SD
Music Box	58	59	DN
Orange Glory	53	73	SD
Orange King	57	71	SD
Peach Passion	63	62	DN
Premier Lemon	44	62	SD
Premier Light Yellow	45	63	SD
Premier Orange	46	64	SD
Procut Amber Glow	58	58	DN
Procut Apricot Lite	62	64	DN
Procut Bicolor	68	62	DN
Procut Bicolor Plus	68	64	DN
Procut Brilliance	68	64	DN
Procut Early Orange	52	61	SD
Procut Gold	60	59	DN
Procut Lemon	62	63	DN
Procut Orange	55	62	SD
Procut Peach	62	62	DN
Procut Peach Blush	62	61	DN
Procut Red	72	72	DN
Procut Red Lemon Bicolor	62	62	DN
Procut White Lite	58	69	SD
Procut Yellow	58	65	SD
Procut Yellow Lite	62	62	DN
Red Hedge	61	60	DN
Ring of Fire	66	69	DN
Solara	53	71	SD
Sonya	65	68	DN
Soraya	79	80	DN
Starburst Gold	64	64	DN
Starburst Greenburst	72	64	LD
Starburst Panache	61	63	DN
Strawberry Blonde	65	63	DN
Sunbright	57	78	SD
Sunbright Supreme	52	75	SD
Sunny	56	79	SD
Sunrich Gold	52	67	SD
Sunrich Lemon Summer	51	72	SD
Sunrich Orange	53	71	SD
Sunrich Orange Summer	49	69	SD
Sunrich Summer Lemoncello	48	66	SD
Tapuz	54	77	SD
Tavor Double	58	60	DN

Tavor Flash	59	64	DN
Tavor Orange Joy	53	67	SD
Terra Cotta	83	80	DN
TH 472	48	68	SD
The Joker	63	61	DN
Tiffany	50	79	SD
Tosca	51	68	SD
Valentine	58	65	DN
Vincent Choice	47	56	SD
Vincent Fresh	47	54	DN
Zahav	55	77	SD
Zebulon	68	66	DN
Zohar	51	72	SD

In summary, about half of the varieties tested by 2015 were insensitive to daylength during the first 3 weeks after emergence, and 42% flowered significantly earlier in short daylength (short-day plants). Four percent flowered significantly earlier in long days. Response to daylength accelerates flowering, but does not prevent it, so can be termed 'facultative'.

2. Rudbeckia daylength response

The importance of daylength is also confirmed by the flowering behavior of the perennial Rudbeckia hirta when planted on different dates in spring and summer. As sowing and transplanting dates progressed from early March to July, varieties like 'Indian Summer' and 'Prairie Sun' showed progressively fewer flowers per plant, and shorter stem lengths (Table 2).

Table 2. Rudbeckia yield and stem length when planted on 4 dates in spring and summer 2006.

	Stems per plant			Stem length, cm		
Sowing date	Indian Summer	Goldilocks	Prairie Sun	Indian Summer	Goldilocks	Prairie Sun
March 8	32	36	30	47	41	42
May 1	18	12	17	47	36	42
June 1	--	7	7	--	34	36
July 1	0	1	0	0	26	0

To determine if the decreased flowering and shorter stem lengths were controlled by daylength, 'Prairie Sun' plants were transplanted into a high tunnel on Aug. 20, and the daylength extended to 16 h with artificial lights giving off light intensities of 1.6 umoles/m^2/sec, or not extended.

Table 3. The effect of the type of light on stem length and yield of Prairie Sun rudbeckia transplanted to a high tunnel on Aug. 20, 2009.

Light treatment	Stem length, cm	Stems/plant
No lights	18	3.7
Solar lights (low intensity)	36	5.6
Mains lights (> 1.6 Umoles)	68	8.7

Light treatment increased stem length and stem numbers per plant (Table 3). Light intensity perceived by the plants was an important factor in daylength response. In a greenhouse study, Rudbeckia was placed at right angles to an artificial light source. Plants required at least 2 umoles/m2/sec to produce flowers with extended stems (Fig. 2). The results indicate that *Rudbeckia hirta* is a long-day plant for flowering. Only a few varieties have been tested for this response, and there appear to be differences, but more work is needed. From a practical standpoint, the largest number of long stems are produced by plants that are established early in spring in temperate environments. Unlike the daylength-sensitive sunflower varieties described above, for which an initial 3-week exposure to the correct photoperiod is sufficient, *Rudbeckia* requires long photoperiod for the entire flowering season. Extending the daylength with sufficient light would require 9-watt fluorescent lights every 6 ft. of bed length, a cost perhaps not justified by the value of the harvested stems.

Fig. 2. Lights at end of bench extended daylength to 16 h, in contrast to 12 h away from lights.

3. Sunflower topping

Sunflower varieties developed for use as cut flowers have been selected to produce a single stem without branches, and high yields are achieved by growing many plants per unit area. For many of these varieties, cutting off the plant tip while the plant is still young forces it to produce branches from the lower leaf axles. This topping results in more stems per plant crowded into the same space and reduced flower size and shorter stems. Our experiments have attempted to reduce the negative effects of topping and are summarized below.

In the first 2 experiments, plants of ‘Procut Orange’ and ‘Sunrich Orange’ were started in the greenhouse and then transplanted to the field at 9 x 9 in. spacing. They were then topped when they had either 4 or 6 expanded leaves. Removing the plant tops tripled stem numbers, reduced stem length and flower size, and delayed flowering by a week (Table 4).

Table 4. Effect of plant top removal, leaving either 4 or six expanded leaves, on flowering characteristics of 'Procut Orange' and 'Sunrich Orange' sunflowers in 2005.

Treatment	Stems/plant	Stem length, cm	Flower disk diameter	Time of flowering, days
Not topped	1.0	115	7.8	63
Topped at node 4	2.6	78	5.0	70
Topped at node 6	3.5	72	4.4	70

The reduced flower size due to topping increases the yield of marketable stems, but these were small. To find if wider spacing of topped plants would remedy this problem, we compared topping at 9 x 9 in. spacing with 12 x 12 in. Reducing crowding increased flower size by 1 cm but decreased flower yield per 1000 ft^2 (Table 5, Fig. 3). Unless a grower has a strong need for larger flowers, combining topping with close spacing would appear to be best.

Table 5. Effect of plant top removal and spacing on yield and flower stem characteristics. Averages of 2 years trials with 'Procut Orange' and 'Sunrich Orange' sunflower.

Treatment, spacing, top	Yield, stems/plant	Yield, stems/1000 ft^2	Disk dia., cm	Stem length, cm	Time of flower., days
9 x 9, not	1	222	8.7	139	64
9 x 9, topped	2.9	638	5.4	78	70
12 x 12, not	1	167	9.4	132	64
12 x 12, topped	3.3	553	6.3	92	68

Fig. 3. Topped 'Procut Orange' stems grown at 12 in. spacing (left), or 9 in. spacing.

Some sunflower varieties used as cut flowers freely produce branches and are attractive to home gardeners who appreciate their extended flowering period. While branching varieties would seem suitable as cut flowers, the harvest of the plant's primary flowering stem removes the primary branches that might form the successive stems. We therefore compared the effect of topping on these varieties with the non-branching types. In an experiment conducted in 2011, the branching lines 'Starburst Lemon Aura' and 'Goldrush' produced similar yields as the unbranched line 'Procut Amber Glow' (Table 6). In this trial, the branching variety 'Starburst Lemon Aura' produced the most stems when topped.

Table 6. Yield of cut flower stems of 3 varieties of sunflower in 2011, averaged across 6 x 6, 9 x 9 and 12 x 12 in. spacing.

Varieties	Yield, stems/1000 ft^2	
	Not topped	Topped
Starburst Lemon Aura	2193	9264
Goldrush	2881	6665
Procut Amber Glow	2243	6727

A second variety trial comparing branching and non-branching lines was conducted in 2015. Plants were transplanted to 9 x 9 in. spacing and topped at the 6-leaf or10-leaf stage, about 5 days apart. The non-branching varieties produced fewer stems after topping than the branching variety (Table 7). Late topping reduced branch numbers in the single stem varieties. Among the single stem varieties, branching tendency also varied. The results emphasize that topping needs to be tried on a small scale first before widespread use.

Table 7. A comparison of branching tendency of 4 sunflower varieties in response to topping at the 6-leaf or the 10-leaf stage in 2015.

Variety, branching?	Yield, stems/plant		
	Not topped	Topped at 6-leaf stage	Topped at 10-leaf stage
Procut Lemon, no	1.0	2.8	2.3
Procut Gold, no	1.0	3.3	1.0
Sunrich Orange, no	1.0	3.2	1.7
Goldrush, yes	1.0	4.7	5.6

From a mechanical standpoint, removing the plant tip is easier to do later in the pre-flowering stage, as the space between leaves increases, but this is also the time that the number of branches formed is reduced (Table 7). Clipping with hedge shears or string trimmer is harder to do at the 6-leaf stage without damaging the remaining leaves, so this may limit the use of topping on a large scale.

4. Topping of other cut flower species:

Lisianthus

In experiments conducted over 3 years, in which lisianthus transplants were topped when being transplanted or about 2 weeks later, yields were either not affected or slightly increased. The treatment delayed flowering by one to two weeks, shifting the season's harvest later. Stem length increases due to topping varied from none to about 10% increase over controls. In summary, removing the plant top in the pre-flowering stage is not beneficial enough to be recommended.

Snapdragon

Snapdragon varieties grown as cut flowers are grouped into earliness groups according to the time they would be grown in the greenhouse. Group I types are relatively early flowering; Group IV lines are grown under long day conditions of the summer and are later-flowering and taller, and the intermediate Group II and III varieties grow best in spring and fall seasons. For culture in the field in Upstate NY, outdoor culture is practiced with a spring transplanted crop that flowers from early summer on; snapdragons grown in the high tunnel are transplanted in midsummer and harvested during fall. In two years of experiments, topping leaving 7 leaves in both seasons increased stem yields from 25 to 48%, but delayed harvests by about 2 weeks. Stem length was little affected by topping, but there were big differences in the reaction of flowering types to both spring outdoor and fall tunnel production (Table 8).

Table 8. Yields and earliness of 5 snapdragon varieties grown in a spring field trial and a fall-planted high tunnel trial in 2007.

	Spring field trial			Fall tunnel trial		
Treatment, (group)	Stem length, cm	Stems per plant	1st harvest, days from sowing	Stem length, cm	Stems per plant	1st harvest, days from sowing
Control	53	10	91	62	8	67
Topped	50	13	109	60	11	84
Stat. signif.[1]	*	**	***	*	***	***
Chantilly (I)	47	12	90	56	11	72
Animation (II)	50	13	94	58	10	69
Apollo (II-III)	50	15	94	62	11	74
Potomac (III)	51	8	108	64	7	82
Opus (III-IV)	59	10	113	67	7	80
Stat. signif.[1]	***	***	***	***	***	***

[1]Statistical significance: *slightly, **moderately and ***very significant differences among values above the column of numbers

The winter and intermediate lines produced more stems in each trial, and flowered earlier, but on shorter stems. In 2007, high temperatures during the summer in the high tunnel before flowering began caused the cool-temperature adapted Chantilly to lose its flower buds on the earliest stems (Fig. 4). The results indicate that topping could be a useful practice in snapdragon production.

Larkspur

Fig. 4. Fall-seeded larkspur at rear, and spring-seeded in foreground.

Larkspur is a winter-hardy cut flower crop that can be transplanted into the high tunnel in early April. Topping at the 6-leaf stage delayed flowering about 5 days but had little effect on flower yields in 2 years of trials. Stem length distribution differed, however, in that the topped plants had stems of uniformly intermediate length, while non-topped plants had a main stem of over a meter length, as well as short branches. The most practical solution in high tunnel culture of larkspur turned out to direct-seed the plants in the tunnel beds in the fall at relatively high density (6 x 6 in. spacing in 5 rows per bed and three seeds per spot). At this density, branching was reduced but long stems were produced, and the crop flowered 3 weeks earlier than the spring-transplanted crop (Fig. 4).

Stock *(Matthiola)*

Stock is an attractive, early-flowering scented cut flower. We topped 4 varieties in a high tunnel in 2009, and got a very definitive answer: only one topped plant in the entire experiment produced a flower (Fig. 5). **So don't top stock!**

Fig. 5. Topped stock plants 2 weeks after apex removal.

5. Overwintering trials in the high tunnel

Tunnel temperatures

High tunnels are structures having a metal or wooden frame, usually covered with clear polyethylene film to protect crops grown inside from rain and wind, and to moderate the temperature. Under conditions of Upstate NY, they extend the growing season at both the beginning and end, compared to outdoors. Further climate modification can be achieved by covering the crop in the high tunnel by a low tunnel, usually 2-3 ft tall, held up by wire or plastic pipe hoops. Temperatures at plant level were monitored in late April 2006 during and after a frosty night (Figs. 6, 7). Without a low tunnel, high tunnel air temperature was only slightly warmer than outside air. The low tunnel cover materials had less effect on crop air temperatures, but the clear plastic low tunnel cooked the plants, so venting low tunnels during the day is mandatory.

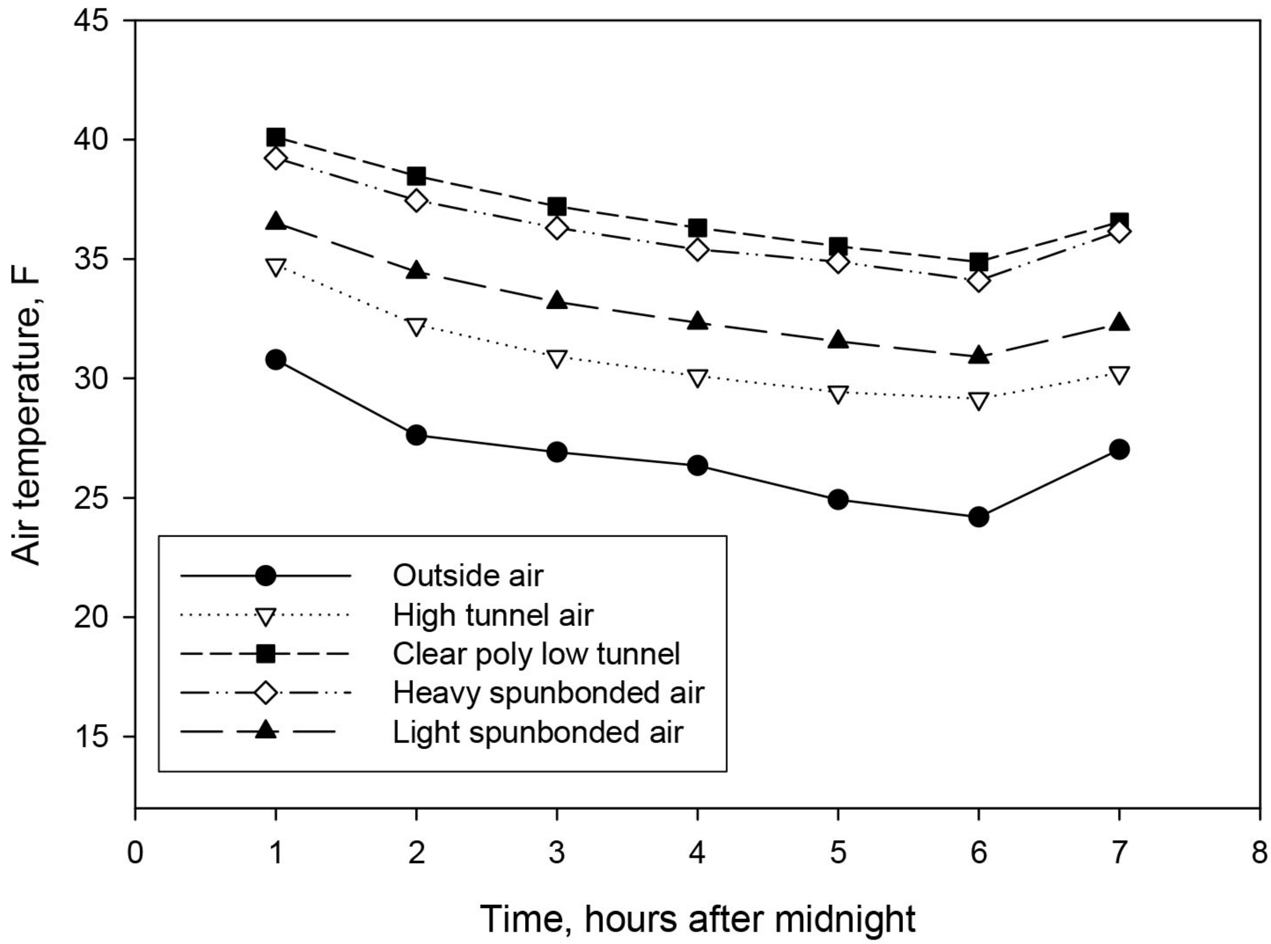

Fig. 6. Air temperatures in high and low tunnels on the morning of April 26, 2006.

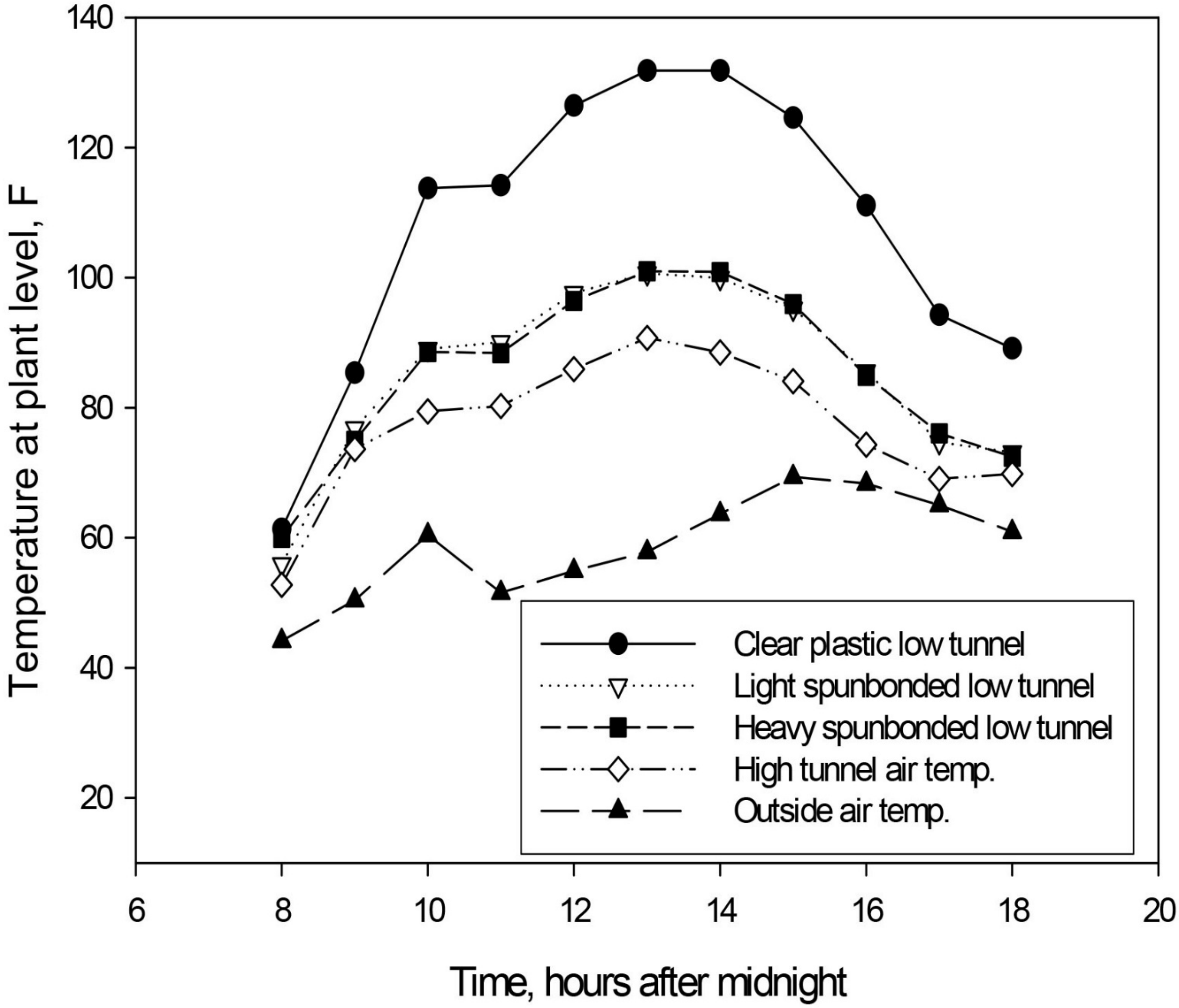

Fig. 7. Maximum air temperatures on April 26, 2006 in the high tunnel and in low tunnels erected inside it.

Overwintering anemone and ranunculus

Fig. 8 'Amadine Yellow Picotee' ranunculus, shown on April 29, 2013.

Anemone and ranunculus are cut flowers normally grown in early spring, but use of high and low tunnels have allowed the crop to be started in December, and after a presprout period of 3 weeks, to be planted in the high tunnel. For the 2013 and 2014 winters, during which low temperatures were close to long-term averages, covering the beds in the high tunnel with low tunnels allowed these crops to be harvested a week to 11 days earlier, and slightly increased stem length. The effect of pre-sprouting the corms before planting was detrimental to ranunculus stand and yield, and requires extra care in watering and maintaining hydration after transplanting. The 2015 trial was injured by low temperatures that dipped to 10 F in February, pointing out that even the combination of high and low tunnel covers was insufficient for plant survival. The results indicate that these crops can be grown in most winters in Region 5, or further south (Fig. 8).

Overwintering snapdragons

As described above when showing results of snapdragon topping, the crop can be grown in a high tunnel, transplanted in mid-summer and harvested until late fall. But why not extend the harvest season by overwintering the crop, with or without protection from a low tunnel? We did that in experiments in 2013 to 2015. It appears that snapdragon is hardier than anemone and ranunculus, in that the very cold winter of 2014/15 that injured the latter even without low tunnel protection allowed some growth and yield of snaps (Table 9). Survival differed between the two varieties.

Table 9. Winter survival and early yield of two varieties of snapdragon when grown in a high tunnel and protected by a low tunnel or not. Trial planted in June and July 2014.

Low tunnel cover	Variety	Winter survival, %	Yield, stems/ft^2
None	Maryland White	22	0.2
None	Supreme Light Lavender	69	2.0
Covered	Maryland White	60	4.8
Covered	Supreme Light Lavender	90	6.8

Sowing dates of June 3 and July 3 did not matter in this experiment, but the additional yield obtained in the second season was significant, especially since these plants started flowering three weeks earlier than the spring-planted outdoor crop. Yields of seven snapdragon varieties planted into the high tunnel the previous year differed and was correlated with their maturity group (Table 10). The winter survival of early flowering varieties (Groups 1 and 2) was lower than those flowering later. This may be related to possible lower carbohydrate reserves of the early lines at the beginning of winter, but that needs to be checked.

Table 10. Yield responses among snapdragon varieties sown in June 2013 in a high tunnel, then overwintered and their survival rate over winter.

Variety	Maturity Group	Stems/ft²			Winter survival, %
		Fall 2013	Spring 2014	Total	
Chantilly Velvet	1-2	22.6	16.4	39.0	63
Purple Twist	2	17.4	1.2	18.6	8
Trrumpet Pink	1-2	19.4	9.9	29.3	44
Madame Butterfly Mix	3-4	10.0	15.1	25.1	72
Snappy Tongue	3-4	14.3	18.6	32.9	80
Supreme Light Lavender	2-3	12.8	10.1	22.9	66
Potomac Lavender	3-4	12.5	15.5	28.0	98
Average		15.6	12.4	28.0	61

6. Transplant crowding

The methods used by cut flower growers for raising transplants often vary, based on space constraints and weather conditions. To probe how flexible cut flower species are in the space required in the seedling tray, and the time of transplanting, we tested these factors with two species.

Lisianthus. In 2008-2010, two varieties were sown in either 72-cell or 210-cell trays and transplanted to the field in early May or two weeks later. Transfer to the larger cell size in early May with the later transplanting was also tried. Lisianthus consistently showed no significant change in stem length, yield or earliness as a result of these treatments, affirming that this species is tolerant of early pre-transplant stress.

Godetia. The same date of planting and cell size treatments were done with godetia over 3 years, but the results were very different. Reducing cell size by using the 200- cell tray, especially if delaying transplanting 2 weeks, caused plants to stay spindly and short in the field, and greatly reduced performance (Fig. 9). Survival of the spindly transplants also was reduced after transplanting. This species is more sensitive to crowding in the seedling stage than lisianthus.

Fig. 9 Effect of cell size and delayed transplanting on plant size of godetia.

7. Delphinium longevity

Cut flower varieties of delphinium have a notoriously short life span when grown from seed and transplanted at our trial grounds in Ithaca. Use of cooling ground covers such as straw or silver reflective mulch made no difference in stand, and treatment of the seedlings with the beneficial fungus Trichoderma harzianum at transplanting also had no effect on plant stand. In both these trials, varietal difference were significant, however, with 'Candles White Shades' having greater longevity than 'Guardian' in 2007, and 'Centurion' having nearly a complete stand at the end of the season compared to 'Guardian' in 2010. A larger variety trial was started in 2013 and continued into 2014 (Table 11). Varieties differed markedly in the rate of plant stand decline, and the yield of stems in the second year. We did not trace the root pathogen that might be responsible for plant death.

Table 11. Trial of 7 delphinium varieties transplanted in 2013, and overwintered into 2014, showing plant stands in late fall of both years, and the yield per unit area in 2014.

Variety	Plant stand, %		Yield, stems/ft^2,
	2013	2014	2014
Centurion White	99	98	7.5
Centurion Rose	97	93	9.7
Pacific Giant Percival	93	78	9.8
Guardian Blue	79	58	6.2
Aurora Blue	94	53	3.8
Candle Blue	92	31	5.3
Pacific Giant King Arthur	69	22	1.9

8. Variety trial summary

Variety trials of various cut flower species were conducted in 2005 to 2015. The choice of species and varieties tested were inspired by the new variety testing program of the Association of Specialty Cut Flower Growers, a non-profit agency based in Oberlin, Ohio, and compared these lines with standard varieties widely grown by cut flower growers. To find the specific trial results, go to the annual reports: flowerbulbs.cornell.edu/cutflowers.

Table 12. Alphabetical listing of cut flower species tested at Cornell University between 2005 and 2015, together with variety numbers in each case, and the year of testing.

Flower species	Year of test
Ageratum	2007 (3), 2015 (6)
Allium	2014 (9), 2015 (9)
Amaranth	2006(6), 2010 (2), 2013 (7)
Ammi, Daucus	2011(2), 2014 (6), 2015 (6)

Anemone	2015 (5)
Aster *Callistephus*	2006 (4), 2010 (6), 2011 (19),
Basil	2011 (4)
Bells of Ireland	2010 (2)
Calendula	2008 (5), 2009 (4)
Campanula	2008 (4),2009 (6), 2010 (3)
Celosia	2006 (5), 2010 (4), 2011 (7) 2012 (7), 2013 (8), 2014 (5),
Cleome	2006 (4)
Centaurea	2015 (6)
Chrysanthemum	2011 (6), 2012 (6)
Cosmos	2011 (4), 2014 (4)
Cynoglossum	2012 (4)
Delphinium	2005 (11), 2009(5), 2014 (4)
Dianthus	2006 (3), 2007 (2), 2009 (3), 2013 (3)
Eryngium	2009 (4)
Eucomis	2012 (4), 2013 (4), 2014 (4), 2015 (7)
Filler cuts	2014 (7)
Godetia	2005 (6)
Gomphrena	2009 (6)2010 (1), 2012 (4),
Grasses	2006 (5), 2011 (4),
Kale	2010 (4), 2014 (5)
Larkspur	2007 (6), 2012 (5)
Lisianthus	2005 (17), 2006 (7), 2007 (15), 2008 (14), 2009 (9), 2010 (15), 2011 (5), 2012 (5), 2013 (11)
Marigold	2010 (6), 2012, (4), 2013 (7), 2015 (7)
Matricaria	2015 (6)
Peppers	2006 (5), 2007 (5), 2011 (28), 2012 (38), 2013 (34), 2014 (13), 2015 (9)
Pumpkin-on-a-Stick	2007 (2), 2013 (3)
Poppy	2014 (4)
Safflower	2012 (5)
Salvia	2007 (7)
Scabiosa	2007 (3), 2010 (4), 2015(4)
Snapdragon	2005 (8), 2010 (4), 2012 (6), 2013 (7)
Statice	2007 (6), 2008 (6), 2015 (7)
Sunflower	Yearly cult. practice trials
Sweet pea	2008 (4)
Trachelium	2005 (7), 2008 (3)
Zinnia	2007 (4), 2008 (8), 2009 (7), 2013 (7)