Long-term Subzero Storage of Specialty Cut Flowers

John Dole and Jen Kalinowski
North Carolina State University

Cold storage of cut flowers is often a necessity. On most farms it is impossible to harvest enough flowers to satisfy the immediate needs of customers and markets. Storing cut flowers at cold temperatures of 35-40°F (2-4°C) reduces respiration and transpiration, allowing them to remain fresh and have a long vase. The duration that flowers can be stored varies with the species from a few days to several weeks. The majority, however, can be stored for only a few days to a week before vase life is reduced.

However, there are many times when it would be greatly advantageous for flowers to be stored longer than a few days. If cut flower growers could hold cut flowers for an extended time, product could be more easily stocked for holidays, markets, and events. In addition, producers would be able to store flowers longer, and continue to supply customers if unexpected warm temperatures speed up production, forcing early harvests.

Subzero temperatures are often avoided because a number of species are sensitive to freezing. However, soon after the introduction of mechanical refrigeration, sub-zero temperatures were tested on cut flowers (Post and Fisher, 1952). They reported species such as tulips and daffodils stored better at 31°F (-0.6°C) than 33°F (0.6°C). It is likely that the cost of having such facilities, the limited number of adaptable species, and the inability to precisely control temperature, discouraged the adoption of sub-zero holding temperatures.

Ice formation is a problem in plant tissue as it damages cell structure and, therefore, cut flower quality. Subzero storage temperatures close to 32°F (0°C) can be used, however, because it is unlikely that ice formation will occur at this temperature due to the soluble solids contained in the water of cut flower stems and flowers. Dormant woody and herbaceous perennial species make use of this supercooling ability every winter to survive sub-zero temperatures for weeks to months (Ashworth et al., 1993; Ashworth, 1990). Harvested cut flowers also have this ability to tolerate temperatures below 32°F (0°C). Cut carnations tolerated 25°F (-4°C) storage for 8 days and still had a normal vase life (Heins et al., 1981). Data from experiments at NC State showed that tulips could be held at 31°F (-0.6°C) for 9 weeks with no loss of vase life and peonies had improved flower opening and quality after being held at 31°F (-0.6°C) for 16 weeks compared to 33°F (0.6°C) (Jahnke et al., 2020).

Post and Fischer (1952) tested a broad range of species: cattleya orchid, carnation, chrysanthemum, gardenia, gladiolus, iris, lily, lily-of-the-valley, peony, tulip, and rose. A number of these species are considered cool-season flowers or frost tolerant. We believe this will be an identifying characteristic of species that can tolerate sub-zero storage. We should mention that in our preliminary testing, three species did not tolerate sub-zero storage: dahlia, limonium and snapdragon. However, we found a positive effect on anemone, campanula, lily, lisianthus, ranunculus, and stock.

One concern for small to medium-sized growers is the ability to put subzero storage to use as two coolers would be best—one for normal cold storage and one for subzero storage. Betsy Hitt (Peregrine Farm, personal communication) previously used a chest freezing to hold cut anemone flowers wrapped in newspaper at just below freezing for an event and indicated that she successfully stored them for a month. This technique would allow ASCFG members to storage smaller quantities in a practical manner.

Objectives

Develop a practical long-term storage process for selected cut flower species using subzero storage. Methods for extended storage of cut flowers, while maintaining flower quality and consumer vase life, would provide the cut flower industry with greater ability to control supply and provide customers with fresh long-lasting flowers.

Procedures

Anemone, campanula, delphinium, freesia, gerbera, larkspur, lily, lisianthus, ranunculus, stock, sunflower, and tuberose flowers were stored at 31 or 39°F (-0.6 or 4.0°C) for 0, 4, 8 or 12 weeks. Bunches of stems were cut to a uniform length removing 1 to 2 in. (2.5 to 10 cm) from the basal stem, depending on the species. Groups were wrapped in newspaper and placed in cardboard boxes lined with polyvinyl wrap. One box per species was held dry at 31°F and one box at 39°F. Relative humidity (RH) was maintained at 80% to 90%. One group per species was removed from each temperature after 4, 8, and 12 weeks of storage. One group from each species was also used as a non-stored control (duration = 0) and taken directly to postharvest evaluation after processing.

After treatment, stems were recut and placed in individual vases filled with tap water in the postharvest evaluation room. Vase life, the number of days a flower remained presentable in tap water, was calculated as the number of days until flowers become >50% wilted or necrotic, or stems collapsed or incurred bent neck. Flower and bud senescence was recorded when >50% of petals or buds were slightly wilted, translucent, or any petals or buds abscised. Stems were considered viable if they remained upright in water with < 50% wilt or petal/bud senescence after 24 hours post-storage and exhibited no signs of mold. Flower opening was rated as either failed to open (FTO), partially open, or fully open. Wilt rating was assigned to all flowers post-storage as either tight (0), slightly wilted (1), moderately wilted (2), or severely wilted (3). The percentage fresh weight loss (FWL) following storage was determined on all species except when stems were of such poor quality after storage (mushy or molded) that they did not remain upright.

Results

Extended storage using sub-zero (31 °F) temperature proved to be feasible for four species (anemone, campanula, larkspur, and ranunculus) with no loss in vase life when stored for 4 weeks at sub-zero temperature (Table 1). Additionally, four species (delphinium, gypsophila, lily, and stock) had 70% to 100% of stems remain viable after 4 weeks of storage below freezing. Vase life for four species (freesia, gerber, lisianthus, and sunflower) was reduced with long-term storage at both temperatures. Tuberose was not tolerant of any storage duration regardless of holding temperature. In some cases 31 °F also reduced mold development as well as other postharvest symptoms such as petal wilting, leaf senescence, etc. A summary of results for all species is presented in Table 2.

Take-Home Message

This study offers a valuable solution for flower producers. By storing flowers at subzero temperatures, they can ensure longer vase life and better match supply with market demand. Especially during times when unexpected weather conditions speed up flower production, this method offers a fallback to manage early harvests effectively.

Citations

Ashworth, E.N., V.E. Stirm, and J.J. Volenc. 1993. Seasonal variations in soluble sugars and starch within woody stems of *Cornus sericea* L. Tree Physiol. 13:379-388.

Ashworth, E.N. 1990. The formation and distribution of ice within *Forsythia* flower buds. Plant Physiol. 90:718-725.

Heins, R.D. G.S. Howell and H.F. Wilkins. 1981. The influence of sucrose, ethanol and calcium nitrate on the freezing-point and long-term low-temperature storage of carnation flowers. Scientia Hortic. 14:269-275.

Jahnke, N.J., J.M. Dole, B.A. Bergmann, G. Ma, and P. Perkins-Veazie. 2020. Extending cut *Paeonia lactiflora* Pall. storage duration using sub-zero storage temperatures. Agronomy 10(11): 1694.

Post, K and CW Fischer. 1952. The commercial storage of cut flowers. Ext Bull Cornell Agric Expt Stn. 853:14 pp.

Table 1. Post-storage evaluation of 13 cut flower species to determine the effects of long-term storage duration and temperature on vase life and viability following durations of 4, 8, or 12 weeks at either 31 or 39 °F (-0.6 or 4 °C).

	Vase life (days)							**Viability (%)**						
	Storage Temperature													
	Control	31°F			39 °F			Control	31°F			39 °F		
	Storage Duration (weeks)													
Species	0	4	8	12	4	8	12	0	4	8	12	4	8	12
Anemone	3.9	3.5	3.3	nv	nv	nv	nv	100	90	40	0	0	0	0
Campanula	12.6	11.0	11.9	nv	10.8	nv	nv	86	93	57	0	93	0	0
Delphinium	13.7	3.2	nv	nv	4.0	nv	nv	100	73	0	0	20	0	0
Freesia	8.1	2.8	nv	nv	3.1	nv	nv	100	67	0	0	67	0	0
Gerbera	11.5	2.0	nv	nv	3.4	nv	nv	100	13	0	13	0	0	0

Gypsophila	15.8	5.0	nv	nv	8.9	nv	nv	100	83	0	0	92	0	0
Larkspur	8.7	6.7	5.0	nv	3.6	nv	nv	100	100	73	0	80	0	0
Lily	8.1	4.9	4.1	3.5	2.4	nv	nv	100	100	73	13	53	0	0
Lisianthus	7.0	2.3	nv	nv	2.4	nv	nv	93	20	0	0	33	0	0
Ranunculus	8.3	6.6	3.3	2.3	4.8	nv	nv	100	93	40	20	27	0	0
Stock	6.0	3.1	nv	nv	nv	nv	nv	93	87	0	0	0	0	0
Sunflower	6.7	2.0	nv	nv	nv	nv	nv	100	27	0	0	0	0	0
Tuberose	7.2	nv	nv	nv	nv	nv	nv	100	0	0	0	0	0	0

[i] nv = stems were not viable post-storage.

Table 2. Summary of results for each species of 31 (-0.6 °C) storage compared to 39 (4 °C).

Anemone	Similar vase life, 31 °F increased viability of stems stored for 4 or 8 weeks, 31 °F reduced leaf senescence and mold.
Campanula	31 °F increased vase life, stems could be stored 4 weeks with 93% viability and up to 8 weeks, but with viability reduced to 57%, 31 °F reduced mold.
Delphinium	Similar vase life, 31 °F increased viability of stems stored for 4 weeks, 31 °F reduced petal wilt, leaf senescence (at 8 weeks) and mold.
Freesia	Similar vase life and viability, 31 °F reduced mold, but increased leaf senescence.
Gerbera	Similar vase life and viability, 31 °F reduced mold.
Gypsophila	Similar vase life and viability, 31 °F reduced petal wilt, leaf senescence and mold.
Larkspur	31 °F increased vase life, stems could be stored 4 weeks with 100% viability and up to 8 weeks, but with viability reduced to 73%, 31 °F reduced mold.
Lily	31 °F increased vase life, stems could be stored 4 weeks with 100% viability and up to 12 weeks, but with viability reduced to 13%, 31 °F reduced petal wilt, bent neck, and mold, hydration and holding solutions had little effect on vase life, pre-holding treatments had either no or a negative effect on vase life.
Lisianthus	Similar vase life and viability, 31 °F reduced mold, but increased bent neck.
Ranunculus	31 °F increased vase life, stems could be stored 4 weeks with 93% viability and up to 12 weeks, but with viability reduced to 20%, 31 °F reduced leaf senescence and mold, but increased bent neck.
Stock	31 °F increased vase life, stems could be stored 4 weeks with 87% viability
Sunflower	31 °F increased vase life, however, only 27% of stems were viable after 4 weeks of storage, 31 °F reduced petal wilt and leaf and petal senescence.
Tuberose	Did not tolerate storage at either 31 or 39 °F.