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# Freezing Date and Duration Effects on Regrowth of Three Species of Container–grown Herbaceous Perennials[1]

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## Abstract

Three species of herbaceous perennials were transplanted from 400 cell–size plugs to 400–ml containers and grown in a glasshouse at 25C day/20C night (78/68F) ± 2C (4F) until October 10. At that time glasshouses were programmed for ambient outdoor temperatures, but maintained above 3C (38F) ± 2C at night. Plants were exposed in controlled programmable freezers to four freezing temperatures [–5, –5, –11 and –14C (23, 18, 12, 7F)] on November 15, 1995, and January 1, 1996. Plants were allowed to remain at each temperature for either 30 or 120 minutes. Plants were then returned to the glasshouse, and rated for survival and salability following 6 weeks regrowth at 15C (59F). The rating scale was subjective and ranged from 1 to 5 (1 = worst, 5 = best, 3 and above considered salable). Regrowth means of all three species declined as treatment temperatures decreased. Although freezing date had a significant influence on regrowth quality of *Aquilegia* and *Dianthus*, only freezing duration influenced *Dianthus* regrowth. Neither factor significantly influenced regrowth quality of *Lavandula*. Treatment temperature and its interaction with freezing date or duration was statistically significant for all three species. All plants remained marketable following exposure to –11C (12F).

**Index words:** hardiness, ornamentals, overwintering, freezing injury, *Aquilegia, Dianthus, Lavandula.*

**Species used in this study:** Columbine (*Aquilegia* L. x *hybrida* 'McKana's Giant' mix), Dianthus (*Dianthus deltoides* L. 'Vampire'), Lavender (*Lavandula angustifolia* Mill. 'Munstead Dwarf').

### Significance to the Nursery Industry

An increasing number of growers in northern regions produce herbaceous perennials in containers, with little information available on cold hardiness. Research in recent years has primarily focused on overwintering systems, but lacked descriptions of specific effects of varying temperatures on hardiness. Such information will enable growers to better schedule crops and predict effects of freezing events. In this study, regrowth of two species was less at an earlier freezing date, whereas duration of freezing at various temperatures affected only one species. Differences, while statistically significant, were often off little practical significance. *Lavandula* was affected by neither durations nor dates used in this study. All three of these species remained marketable to root temperatures of at least –11C (12F). Thus, freezing effects seem to be species dependent, with more research needed on other species so that different species can be grouped together according to amount of overwintering protection required. This would enable easier, more efficient and more cost effective production.

### Introduction

Overwintering is the single most limiting factor in container–growing of nursery plants in northern nurseries (6). Landscape and field–grown plants benefit from the soil's capacity to retain and release heat during the winter, whereas containerized plants are poorly buffered against changes in temperature. Their roots and crowns are, therefore, much more susceptible to low temperature–induced injury (8, 9).

Cold hardiness has been defined as 'the ability or capacity of a plant to survive an unfavorable low environmental temperature' (7). Two prerequisites necessary for cold hardening in plants are: 1) an inherent or genetic capacity to tolerate freezing temperatures, and 2) exposure to the conditions that will induce the hardening process. This expression of the genetic capacity of cold hardiness is termed 'acclimation.' Some recent effort has been devoted to investigation of the genetic component, or response of various perennial species (4).

The environmental component has been investigated for winter wheat crowns, which acclimate as much as 10C (20F) in one week but require approximately four to six weeks for the full development of hardiness potential (2). For potato species, 15 days of cold exposure at 2C (36F) was sufficient to achieve maximum frost hardiness expression (1). In one of the few studies examining acclimation in ornamental herbaceous perennials, Iles and Agnew (5) determined that, when exposed to identical hardening conditions, bare–root crowns of *Sedum* 'Brilliant' acclimated later than *Sedum* 'Autumn Joy' and that 'Autumn Joy' began to acclimate before continual exposure to freezing temperatures.

The purpose of this study was to examine the effect of date and duration of freezing on survival and regrowth of three commonly produced herbaceous perennial cultivars representing different genera.

### Materials and Methods

On July 22, 1995, seedling plugs (400 cell–size) of *Aquilegia* 'McKana's Giant' mix, *Dianthus deltoides* 'Vampire', and *Lavandula angustifolia* 'Munstead Dwarf' were potted into 400–ml containers (4" Kord Ultra) using Metromix 510 (The Scott's Company, Marysville, OH) and placed in a (30 × 40 ft.) glass greenhouse in Burlington, Vermont. All received 150 ppm N from a water soluble 20N–4.4P–16.6K fertilizer (20–10–20, The Scott's Company, Marysville, OH) every other watering until September 1, after which they received only tap water. The greenhouse temperature was main-

[1]Received for publication April 22, 1996; in revised form September 9, 1996. Appreciation is expressed to Raker's and Sons, Litchfield, MI and The Scott's Company, Marysville, OH, for their generous donation of plants and materials. Research funds provided through Hatch Project VT–503, the Vermont Association of Professional Horticulturists, **The Horticulture Research Institute, 1250 I St. N.W., Washington, DC 20005**, and New England Grows, South Natick, MA.

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tained at 25C day/20C night (78/68F) ± 2C (4F) through October 10. At that time, greenhouse exhaust fans were programmed to 'maximum cooling' in order to approximate ambient outdoor temperatures (although temperatures were prevented from falling below 3C (38F) ± 2C in order to prevent freezing of water pipes).

On November 15, plants were randomized and each species subjected to all combinations of a 2 × 2 × 5 factorial experiment, involving two freezing dates, two freezing durations and five low temperature levels. Freezing took place on November 15 and January 1, using durations of 30 and 120 min at each temperature level. The five temperature levels included a 3C (38F) nonfrozen control, –5, –8, –11, and –14C (23, 18, 12, 7F). Eight plants were randomly assigned to each factor–level combination.

Plants were frozen in an insulated chest freezer (Wood's model UWC15–ZL/E, W.C. Wood Co., Guelph, Canada), equipped with a Dyna–Sense Mark III programmable controller (Scientific Instruments, Skokie, IL). In order to minimize variability within the freezer and insure adequate air circulation, a circulating fan (model E89061, Tandy Corp., Ft. Worth, TX) was placed on the freezer floor, and plants were kept above the freezer floor on wooden shelves. To minimize differences in moisture between pots, plants were watered to capacity 24 hrs before freezing. Freezer accuracy at setpoint temperatures was within 1C (2F). Media temperatures were verified at each setpoint using thermometers placed in media–filled pots randomly scattered throughout the freezers.

For each of the four freezing techniques used in this study, the freezer was loaded and held at –2C (28F) for 40 hrs to insure that all pots were uniformly frozen prior to dropping to target temperatures. The freezer temperature was then dropped 2C (4F) ± 0.5C (1F) per hour until reaching the first temperature setpoint (–5C, 23F), and held for either 30 or 120 minutes prior to removing all plants for that treatment temperature. The temperature was then dropped at 2C (4F) ± 0.5C (1F) to the next temperature setpoint, and the process repeated until completing all four temperature levels. At each temperature set–point, all plants had reached the target temperature after 30 minutes and remained there while plants for that treatment were removed. Upon removal from the freezer, all plants were immediately placed back in the greenhouse and held at 3C (38F) until January 10, when the greenhouse temperature was raised to 20C (68F).

Six weeks after freezing, plants were rated both for survival and for regrowth quality as had been done effectively in previous studies (3, 4), reflecting in large part dry weights among other characters such as flowering and foliage appearance. All were rated on a scale of 1 to 5 as follows: 1 = no regrowth and/or up to 100% dieback, 2 = trace regrowth and/or up to 75% dieback, 3 = moderate regrowth and/or up to 50% dieback, 4 = good regrowth and/or up to 25% dieback, and 5 = vigorous regrowth and/or no dieback. Survival was defined in terms of visible shoot regrowth, so that plants which lacked shoot tissue after six weeks of regrowth were considered dead. Regrowth ratings of each species were subjected to an analysis of variance, and F–tests were performed on main factors and interaction between factors.

## Results and Discussion

*Aquilegia* regrowth quality was most significantly influenced by freezing date and treatment temperature (Table 1). Interaction between freezing date and duration, and between freezing date and temperature, were also significant although to a lesser degree than either date or temperature alone. With each freezing treatment, rating decreased with decreasing temperature with a sharper drop on Novermber 15. Plants were marketable six weeks after freezing to –11C (12F) on November 15, but to –14C (7F) on January 1. Regrowth quality was unaffected by freezing duration or by its interaction with temperature or both date and temperature.

*Dianthus* regrowth quality was most significantly influenced by treatment temperature, and by the interaction of temperature with freezing date (Table 2). Freezing date and duration were also found to be significant. Although six weeks after freezing all plants were rated marketable, those

**Table 1. Effect of freezing date, duration and temperature on regrowth quality of *Aquilegia* 'McKana's Giant' mix, 1995–1996.**

| Freezing date | Freezing duration (min) | Treatment temp (C) 3 | –5 | –8 | –11 | –14 |
|---|---|---|---|---|---|---|
| November 15 | 30 | 4.6[z] | 4.3 | 3.8 | 3.4 | 2.3 |
| | 120 | 4.6 | 4.6 | 3.9 | 3.9 | 2.3 |
| January 1 | 30 | 4.6 | 4.6 | 4.5 | 4.0 | 3.4 |
| | 120 | 4.6 | 4.5 | 4.1 | 3.6 | 3.1 |
| ANOVA significance[y] | | | | | | |
| Date (D) | *** | | | | | |
| Duration (L) | ns | | | | | |
| Temp (T) | *** | | | | | |
| D × L | * | | | | | |
| D × T | * | | | | | |
| L × T | ns | | | | | |
| D × L × T | ns | | | | | |

[z]Mean of 8 replicates. Rating scale: 1 = no regrowth, 2 = trace to 25% regrowth, 3 = 26 to 50% regrowth, 4 = 51 to 75% regrowth, 5 = 76 to 100% regrowth. Plants rated 3 and above were considered marketable.

[y]ns, *, **, *** indicate non–significant or significant at the 0.05, 0.01 or 0.001 level, respectively.

**Table 2. Effect of freezing date, duration and temperature on regrowth quality of *Dianthus deltoides* 'Vampire'. 1995–1996.**

| Freezing date | Freezing duration (min) | Treatment temp (C) 3 | –5 | –8 | –11 | –14 |
|---|---|---|---|---|---|---|
| November 15 | 30 | 4.9[z] | 5.0 | 5.0 | 4.5 | 3.6 |
| | 120 | 4.9 | 4.9 | 4.6 | 3.8 | 3.5 |
| January 1 | 30 | 4.9 | 4.1 | 4.3 | 4.5 | 4.0 |
| | 120 | 4.9 | 4.1 | 4.4 | 4.0 | 3.8 |
| ANOVA significance[y] | | | | | | |
| Date (D) | * | | | | | |
| Duration (L) | * | | | | | |
| Temp (T) | *** | | | | | |
| D × L | ns | | | | | |
| D × T | *** | | | | | |
| L × T | ns | | | | | |
| D × L × T | ns | | | | | |

[z]Mean of 8 replicates. Rating scale: 1 = no regrowth, 2 = trace to 25% regrowth, 3 = 26 to 50% regrowth, 4 = 51 to 75% regrowth, 5 = 76 to 100% regrowth. Plants rated 3 and above were considered marketable.

[y]ns, *, **, *** indicate non–significant or significant at the 0.05, 0.01 or 0.001 level, respectively.

**Table 3. Effect of freezing date, duration and temperature on regrowth quality of *Lavandula angustifolia* 'Munstead Dwarf', 1995–1996.**

| Freezing date | Freezing duration (min) | Treatment temp (C) 3 | –5 | –8 | –11 | –14 |
|---|---|---|---|---|---|---|
| November 15 | 30 | 4.5[z] | 4.3 | 4.4 | 3.1 | 2.5 |
| | 120 | 4.5 | 4.4 | 4.0 | 3.0 | 2.5 |
| January 1 | 30 | 4.5 | 4.3 | 4.3 | 3.6 | 2.9 |
| | 120 | 4.5 | 4.0 | 3.9 | 3.4 | 2.9 |
| ANOVA significance[y] | | | | | | |
| Date (D) | ns | | | | | |
| Duration (L) | ns | | | | | |
| Temp (T) | p = .001 | | | | | |
| D × L | ns | | | | | |
| D × T | ns | | | | | |
| L × T | ns | | | | | |
| D × L × T | ns | | | | | |

[z]Mean of 8 replicates. Rating scale: 1 = no regrowth, 2 = trace to 25% regrowth, 3 = 26 to 50% regrowth, 4 = 51 to 75% regrowth, 5 = 76 to 100% regrowth. Plants rated 3 and above were considered marketable.

[y]ns, *, **, *** indicate non–significant or significant at the 0.05, 0.01 or 0.001 level, respectively.

frozen November 15 decreased in quality with decreasing temperature more so than those frozen January 1. Regrowth quality was not significantly influenced by interaction between duration and date, duration and temperature, or date, duration and temperature.

The only factor which significantly influenced regrowth quality of *Lavandula* was treatment temperature (Table 3), and there was no significant interaction of factors. From both freezing dates plants were rated marketable to –11C (12F) six weeks after freezing.

All three species were rated marketable six weeks after freezing roots to –11C (12F), on both dates and for both durations, and could be grouped to provide this level of root protection from cold. This result may only apply to the specific hardening conditions used in this study, with no exposure to freezing prior to treatment as may be found in an overwintering house with minimal heat. Cycling temperatures and nutrition affect freezing results as will exposure to natural hardening conditions (3), now under study, including fall frosts and freezes.

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