Controlled Freezing of Twenty-three Container-grown Herbaceous Perennials[1]

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Abstract

Twenty-three containerized herbaceous perennials were acclimated to ambient outdoor temperature and photoperiod until November 19, when they were moved into a greenhouse and held at 3C (37F) until February 15. At that time, plants were exposed for 30 minutes to a range of subzero temperatures, and returned to the greenhouse for forcing. Plants were rated for survival and salability following 6 weeks regrowth at 15C (59F), using a subjective scale of 1 to 5 (1 = worst, 5 = best, 3 and above considered salable). Of the 23 perennials studied, 15 survived after exposure to at least –8C (18F), however, 40% of the species and cultivars surviving at this temperature sustained a level of injury which rendered them unsalable. Most plants were rated salable at treatment temperatures 3 to 6 degrees warmer than their respective lowest survival temperatures (LST's). *Phlox* 'Chattahoochie', *Phlox* 'Morris Berd', and *Tiarella* 'Laird of Skye' remained salable after exposure to –11C (12F). *Campanula takesimana*, *Heuchera americana* 'Dales Strain', *Penstemon fruticosus* 'Purple Haze', *Rosmarinus officinalis* 'Arp', *Tiarella* 'Running Tapestry', and *Tiarella cordifolia* 'Slick Rock' remained salable after exposure to –8C (18F). *Erodium reichardii* 'Roseum', *Hebe macrocarpa* 'Margaret', and *Verbena* 'Homestead Purple' remained salable after exposure to –5C (23F). Only the unfrozen controls of *Houttuynia cordata* 'Chameleon' and *Thelypteris kunthii* remained salable. Treatment means for *Ceratostigma plumbaginoides* were not significantly different and all 6 *Hibiscus* cultivars ('Blue River II', 'Disco Belle Pink', 'Disco Belle Rose Red', 'Disco Belle White', 'Lord Baltimore' and 'Southern Belle') failed to survive any of the temperature treatments. In general, plants showed a gradual decline in salability with decreasing temperatures.

Index words: hardiness, freezing, ornamentals, overwintering, injury.

Species used in this study: Bellflower (*Campanula takesimana* Nakai); Leadwort (*Ceratostigma plumbaginoides* Bunge); Heron's Bill (*Erodium reichardii* Murray 'Roseum'); Hebe (*Hebe* Comm.ex Juss. *macrocarpa* 'Margaret'); Coral Bells (*Heuchera americana* L. 'Dales strain'); Hibiscus cultivars (*Hibiscus* L. 'Blue River II', 'Disco Belle Pink', 'Disco Belle Rose Red', 'Disco Belle White', 'Lord Baltimore' and 'Southern Belle'); Chameleon plant (*Houttuynia cordata* Thunb. 'Chameleon'); Beard-tongue (*Penstemon fruticosus* (Pursh) greene 'Purple Haze'); Garden phlox (*Phlox paniculata* L. 'David'); Phlox cultivars (*Phlox* L. 'Chattahoochie' and 'Morris Berd'); Korean rock fern (*Polystichum tsussimense* (Hook.) J Sm.); Rosemary (*Rosmarinus officinalis* L. 'Arp'); Japanese beech fern (*Thelypteris* Schmidel *kunthii*); Foamflower (*Tiarella cordifolia* L. 'Slick Rock'); Foamflower cultivars (*Tiarella* L. 'Laird of Skye' and 'Running Tapestry'); Vervain (*Verbena* L. 'Homestead Purple').

Significance to the Nursery Industry

As the popularity of containerized herbaceous perennials continues to increase, so does the need for information regarding cold hardiness limitations of individual species and cultivars. With this information, growers will be better able to determine the appropriate level of overwintering protection required, thus minimizing the potential for underprotection or overprotection (both conditions translating into lost profit). In this study, all but 3 species survived media temperatures of at least –8C (18F). It was also determined, however, that 40% of the species and cultivars which survived at this temperature sustained a level of injury which rendered them unsalable. Although they retained the capacity for both root and shoot regrowth, they were slow to initiate growth and were poorly developed. Ideally, overwintering systems should confer a level of protection which would prevent such injury. This research examined both survival and salability of a number of herbaceous perennials exposed to a range of freezing temperatures.

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Introduction

Containerized production of herbaceous perennials has become increasingly popular as an alternative to field production (11, 15). Unfortunately, roots and crowns in overwintering containers may be exposed to lower temperatures relative to plants overwintered in-ground (14, 15). In-ground plants benefit from the capacity of soil moisture to retain heat, and the depth of submersion of regenerative tissues may be a critical factor in determining their survival temperature (13). In contrast, containerized plants are poorly buffered, leaving regenerative tissues susceptible to low temperature-induced injury.

Cold hardiness research has failed to keep pace with the perennial plant industry (3, 15). As a result, growers are often resigned to learning hardiness limitations through personal experience and production losses. Although hardiness zones can serve as useful guides for estimating the hardiness of landscape plants, they may be unsuitable for making generalizations about hardiness limitations of containerized plants.

There are a wide variety of overwintering systems that have been shown to effectively minimize cold penetration (1, 2, 4, 5, 7, 9, 10). Unfortunately, many of these systems can be both costly and labor-intensive. In addition, growers who chose to offer a large number of perennial species may be confronted with a variety of species-specific overwintering requirements, yet it is not uncommon for growers to consolidate crops and utilize a single overwintering system (10). In light of the scarcity of information regarding cold hardiness limitations of individual species, this practice may be the most conservative, as well as the most practical.

The purpose of this study was to expose plants to a range of freezing temperatures in order to determine the lowest survival temperature (LST) and the temperature below which plants are no longer salable.

Materials and Methods

On September 1, 1994, 48 plants of each of the following species were upshifted from plugs: *Campanula takesimana*, *Ceratostigma plumbaginoides*, *Heuchera americana* 'Dale's Strain', each of 6 *Hibiscus* cultivars ('Lord Baltimore', 'Blue River II', 'Disco Belle White', 'Disco Belle Pink', 'Disco Belle Rose Red', and 'Southern Belle'), *Houttuynia cordata* 'Chameleon', *Penstemon fruticosus* 'Purple Haze', *Phlox paniculata* 'David', *Phlox* 'Chattahoochie', *Phlox* 'Morris Berd', *Rosmarinus officinalis* 'Arp', *Tiarella* 'Laird of Skye', *Tiarella* 'Running Tapestry', *Tiarella cordifolia* 'Slick Rock' and *Verbena* 'Homestead Purple'. Due to a shortage of plant material, only 36 plants of the following were also upshifted: *Erodium reichardii* 'Roseum', *Hebe macrocarpa* 'Margaret', *Polystichum tsussimense*, and *Thelypteris kunthii*. All plants were potted into 400 ml pots (Kord ultra 4") using ProMix BX (Premier Brands Inc., Red Hill, PA) and placed on wire racks in full sun. All received 150 ppm N from a water soluble 20N–4.4P–16.6K fertilizer (20–10–20, The Scott's Co., Milpitas, CA) every other watering until October 1, after which they received non-fertilized water. Plants were uniformly watered to capacity at each watering.

Plants were allowed to cold acclimate under natural temperature and photoperiod until November 19, when they were moved into a (30 × 40 ft.) glass greenhouse and held at 3C ± 2C (37F ± 4F). Ambient light intensity and photoperiod were maintained throughout the storage period.

On February 15, all varieties were randomized for freezing. There were a total of 5 freezing treatments, –2, –5, –8, –11 and –14C (28, 23, 18, 12 and 7F), and one control which remained at 3C (37F) throughout the duration of the experiment. Each treatment consisted of 8 replicates (6 for *Erodium*, *Hebe*, *Polystichum* and *Thelypteris*), with 1 pot per replicate. To minimize differences in moisture between pots, plants were watered to capacity 48 hours before freezing.

Freezing took place in 2 Wood's chest freezers (model UWC15-ZL/E, W.C. Wood Co., Guelph, Canada), each equipped with a Dyna-Sense Mark III programmable controller (Scientific Instruments, Skokie IL) and a Radio Shack model E89061 circulating fan (Tandy Corp., Ft. Worth, TX). Freezer accuracy at setpoint temperatures was within 1C (2F). Media temperatures were verified at each setpoint using thermometers placed in media-filled pots in each freezer. There were no cases in which media-filled pots failed to precisely match setpoint temperatures using this technique.

Freezers were initially programmed to hold at –1C (30F) for 40 hours in order to insure that all pots were uniformly frozen prior to dropping to setpoint temperatures. This was verified by visual examination of pots randomly selected from within each freezer. Temperatures were then dropped at a rate of 2C (4F) per hour until reaching the first setpoint temperature, –2C (28F). After holding at this temperature for 30 minutes, 8 plants (6 for *Erodium*, *Hebe*, *Polystichum* and *Thelypteris*) were removed and placed back in the 3C greenhouse. The freezer was then dropped to the next setpoint temperature and the process repeated until completing all temperature treatments. On March 24, the greenhouse temperature was raised to 15C (59F).

Six weeks after freezing, plants were rated for survival and salability. Species which retained shoot tissue were evaluated for both dieback and regrowth, and those which did not were evaluated for regrowth only. In both cases plants were qualitatively 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. Plants rated 3 and above were considered salable. Survival was measured as the ability of each species to display visible shoot regrowth following exposure to the treatment temperatures, so that plants which failed to produce shoot tissue were considered dead.

Data was analysed using a computer-based statistical program (Statmost for Windows, Datamost Corp., Salt Lake City, UT). Analysis of variance was used to determine whether differences between temperature means were significant. Where differences occured, means were separated using Tukey's test.

Results and Discussion

Of the 23 perennials studied, 15 survived exposure to at least –8C (18F), with 10 surviving to –14C (7F) (Table 1). The *Ceratostigma, Phlox* 'David' and *Hibiscus* cultivars were weakly rooted into the transplant medium, and this may have contributed to their poor survival. All others were well-rooted when moved into the greenhouse.

Several species failed to survive exposure to temperatures which one might expect they should, given the relativity of hardiness zone ratings between species. *Houttuynia* and *Thelypteris* are designated as hardy to USDA zones 5 and 4, respectively, yet only the unfrozen controls of these species survived. The *Heuchera* and *Tiarella* cultivars, also rated hardy to zone 4, survived exposure to –14C (7F). In contrast, both the *Penstemon* and *Rosmarinus* survived exposure to –14C (7F), even though they are rated hardy only to zone 6.

Although the lowest survival temperature (LST) is an important consideration when overwintering perennial species, ultimately their salability should be a prime consideration when analyzing the effectiveness of an overwintering system. In this study, the only species which was rated salable at its LST was *Thelypteris kunthii*—and that was the unfrozen control treatment. Most plants were rated salable at treatment temperatures 3 to 6 degrees warmer than their respective LSTs. In general, plants showed a gradual decline in salability with decreasing temperature (Table 2), and it was not well correlated with LSTs.

The roots are one of the most susceptible organs to cold injury in herbaceous plants (12), however many species are capable of root regeneration from rhizomes, basal stems, tubers or other tissues following freezing-induced root injury (8). In tap-rooted species, root regenerative capacity is lost once the tap root is killed, however in rhizomatous and fibrous-rooted species survivability is primarily a function of the temperature threshold below which root regenerative capacity is lost (12). Examination of the roots of plants exposed to temperatures below their 'salability threshhold' showed varying degrees of regrowth following apparent root injury. Subsequent shoot growth was generally smaller and

Table 1. Plant survival (%) at each treatment temperature.

Species	Treatment temperature, C					
	+3	−2	−5	−8	−11	−14
Campanula takesimana	100	100	100	**88**[z]	100	75
Ceratostigma plumbaginoides	25	25	50	25	0	0
Erodium reichardii 'Roseum'[y]	100	100	**100**	100	0	0
Hebe macrocarpa 'Margaret'[y]	100	100	**100**	83	0	0
Heuchera americana 'Dale's Strain'	100	100	100	**88**	88	38
Hibiscus (all cultivars)	0	0	0	0	0	0
Houttuynia cordata 'Chameleon'	**100**	38	0	0	0	0
Penstemon fruticosus 'Purple Haze'	100	100	100	**100**	100	100
Phlox paniculata 'David'	38	75	38	63	50	38
Phlox 'Chattahoochie'	90	100	100	100	**100**	100
Phlox 'Morris Berd'	100	100	100	100	**100**	100
Polystichum tsussimense[y]	100	100	100	33	0	0
Rosmarinus officinalis 'Arp'	100	100	100	**100**	75	25
Thelypteris kunthii[y]	**100**	0	0	0	0	0
Tiarella cordifolia 'Slick Rock'	100	100	100	**100**	100	63
Tiarella 'Laird of Skye'	100	100	100	100	**100**	75
Tiarella 'Running Tapestry'	100	100	100	**100**	100	38
Verbena 'Homestead Purple'	100	100	**100**	100	63	0

[z]Bold indicates lowest temperature treatment resulting in salable plants (quality rating of 3 or above).

[y]n = 6, all others n = 8.

less vigorous than that of warmer treatments, and although they retained the capacity for both root and shoot regrowth, they were slow to initiate growth and were poorly developed.

Controlled freezing studies can be an effective method of comparing hardiness levels among containerized perennial species, however it should be kept in mind that acclimation conditions, procedural factors and freezing techniques may all exert an influence on results. Greenhouse holding conditions in this study prevented plants from being exposed to subfreezing temperatures, and as a result some species may not have obtained their maximum level of hardening. A concurrent study using *Campanula takesimana* examined whether such procedural variables might influence regrowth ratings and LST (unpublished data). Significant effects were attributed to both freezing duration and the number of freezing and thawing cycles. The date on which plants undergo freezing treatments has also been found to significantly influence survival and regrowth quality (6).

Nonetheless, information gained from this and other perennial hardiness research should help growers determine a level of overwintering protection which will not only minimize winter losses, but also allow them to take full advantage of the sales potential offered by containerized plants.

Table 2. Regrowth ratings at each treatment temperature[z]

Species	Treatment temperature, C					
	+3	−2	−5	−8	−11	−14
Campanula takesimana	5.0a[y]	5.0a	5.0a	3.6b	2.8c	1.8d
Ceratostigma plumbaginoides	1.3ns[x]	1.3ns	1.5ns	1.3ns	1.0ns	1.0ns
Erodium reichardii 'Roseum'[w]	5.0a	4.8a	4.3b	2.6c	1.0d	1.0d
Hebe macrocarpa 'Margaret'[w]	4.0a	4.0a	3.7b	2.6c	1.0d	1.0d
Heuchera americana 'Dale's Strain'	4.8a	4.1b	4.1b	3.0c	2.9c	1.4d
Hibiscus (all cultivars)	1.0ns	1.0ns	1.0ns	1.0ns	1.0ns	1.0ns
Houttuynia cordata 'Chameleon'	5.0a	1.5b	1.0c	1.0c	1.0c	1.0c
Penstemon fruticosus 'Purple Haze'	3.8b	4.0a	3.4c	3.1d	2.9e	2.9e
Phlox paniculata 'David'	2.1b	3.1a	1.5bc	2.0bc	1.6bc	1.4c
Phlox 'Chattahoochie'	4.3a	4.3a	3.5a	3.5b	3.3c	2.5d
Phlox 'Morris Berd'	5.0a	5.0a	5.0a	3.8b	3.4b	2.6c
Polystichum tsussimense[w]	2.8a	2.8a	2.3b	1.3c	1.0c	1.0c
Rosmarinus officinalis 'Arp'	5.0a	5.0a	5.0a	3.4b	1.8c	1.3d
Thelypteris kunthii[w]	3.3a	1.0b	1.0b	1.0b	1.0b	1.0b
Tiarella cordifolia 'Slick Rock'	5.0a	5.0a	4.4b	3.0c	2.0d	1.6e
Tiarella 'Laird of Skye'	4.8a	4.5ab	4.4b	3.4c	3.0d	1.8e
Tiarella 'Running Tapestry'	4.9a	4.9a	4.0b	3.3c	2.5d	1.4e
Verbena 'Homestead Purple'	3.9a	3.6a	3.6a	2.4b	1.6c	1.0d

[z]Rated at week 6 with 1 = up to 100% dieback and/or no regrowth, 5 = no dieback and/or aggressive regrowth.

[y]Mean separation using Tukey's test at p = .05.

[x]ns = means not significantly different using F test at p = .05.

[w]n = 6, all others n = 8.

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Generation and Identification of New Viburnum Hybrids[1]

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Abstract

The controlled crossing of fragrant flowered viburnums (*V. carlesii* and its hybrids) with the hardier, rugose foliaged *V. lantana* is unattainable through traditional breeding methods due to incompatibilities within the developing seed. Hybrid plants from these crosses have now been obtained using embryo rescue techniques. Embryos were removed from developing seed 17 days following pollination and placed on WPM medium to promote continued maturation. Genotypes from two crosses, *V. lantana* 'Mohican' x *V. carlesii* 'Aurora' and *V. lantana* 'Mohican' x *V.* x *juddii*, were obtained and verified using RAPD markers. These plants are presently being evaluated for ornamental characteristics and cold hardiness.

Index words: embryo rescue, RAPD.

Species used in this study: Wayfaring tree viburnum (*Viburnum lantana* L. 'Mohican'); Koreanspice viburnum (*Viburnum carlesii* Hemsl.'Aurora'); Judd viburnum *Viburnum* x *juddii* Rehd. (*V. bitchiuense* Mak. x *V. carlesii* Hemsl.).

Significance to the Nursery Industry

The development of new woody landscape plants with improved disease and insect resistance, hardiness and landscape characteristics can be greatly constrained by traditional breeding methods. Embryo rescue techniques can be used to overcome some of these limitations, as demonstrated here with viburnums.

These new viburnums, along with future developments from coupling biotechnology with plant breeding and selection, will help fulfill the need for low maintenance yet highly ornamental plants useful in low input, sustainable landscape plantings.

Currently a significant tool in agronomic and vegetable breeding, Random Amplified Polymorphic DNA (RAPD) analysis offers tremendous potential for ornamental plant breeding and development. Cultivar identification through RAPD analysis provides the advantages of speed, low cost, and technical simplicity (5). In addition, RAPD analysis promises to be an efficient tool useful in plant patent protection (9).

Introduction

The genus *Viburnum* represents a diverse group of highly useful shrubs native to temperate and subtropical regions in Asia, Europe, North America, and South America. Within the genus, fragrant flowers, attractive foliage, ornamental fruit, and vibrant fall color are common (2, 3). However, no

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