Cold Hardiness Potential of Ten *Hydrangea* Taxa[1]

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Abstract

Nine *Hydrangea macrophylla* (Thunb.) Ser. and one *H. serrata* (Thunb. ex J.A. Murr.) Ser. cultivars were evaluated for midwinter cold hardiness, acclimation, and deacclimation to identify cultivars with increased cold tolerance. *Hydrangea macrophylla* 'Endless Summer', 'Mariesii Variegata', and 'Veitchii' acclimated later than all other cultivars. 'Générale Vicomtesse de Vibraye' acclimated first, and was cold hardy to –6C (21F) by September 28, 2000. The greatest cold hardiness in all cultivars occurred on January 5, 2001. Maximum cold tolerance in all cultivars was within a 6C (11F) range with 'Endless Summer' being the least cold hardy [–18C (0F)], while 'Dooley', 'Générale Vicomtesse de Vibraye', 'Mme. Emile Mouillère', and *H. serrata* 'Bluebird' possessed the greatest cold hardiness [–24C (–11F)] on January 5. Deacclimation in all cultivars began after the January 5 collection date as indicated by the February 1, 2001, data. On March 1, 2001, 'Ayesha' and 'Mariesii Variegata' survived only 4C (39F) while all other cultivars survived at least –6C (21F).

Index words: remontant flowering, deacclimation, acclimation, *Hydrangea paniculata*, *Hydrangea arborescens*.

Species used in this study: *Hydrangea macrophylla* 'All Summer Beauty', 'Ayesha', 'Dooley', 'Endless Summer', 'Générale Vicomtesse de Vibraye', 'Mme. Emile Mouillère', 'Mariesii Variegata', 'Nikko Blue', 'Veitchii', and *H. serrata* 'Bluebird'.

Significance to the Nursery Industry

The susceptibility of *H. macrophylla* to freezing injury limits its flowering potential in both southern and northern regions. Early cold acclimation in the fall and late deacclimation in the spring are essential for flower survival in areas prone to untimely frosts. Identifying cultivars with increased cold adaptability would significantly enhance the marketing potential of *H. macrophylla* as a reliable flowering shrub. Data obtained from laboratory cold hardiness studies are useful in selecting breeding parents to increase cold hardiness. Also, laboratory data for many previously tested cultivars corresponded closely with field performance. Results from these laboratory cold hardiness tests also agreed with field observations of *Hydrangea macrophylla* cultivars. All cultivars tested reached maximum cold hardiness by January 5. Maximum laboratory cold hardiness of 'Endless Summer' was –18C (0F), and all other cultivars tested were hardy to at least –21C (–6F). *Hydrangea macrophylla* 'Dooley', 'Générale Vicomtesse de Vibraye', 'Mme. Emile Mouillère', and *H. serrata* 'Bluebird' were most cold hardy [–24C (–11F)] on January 5. Cultivars that are more resistant to freezing temperatures throughout the fall, winter, and spring could be marketed in place of less hardy cultivars.

Introduction

Hydrangea macrophylla, native to coastal regions of Japan, is one of the most popular landscape plants worldwide (11, 12). Plants of *H. macrophylla* thrive in maritime regions but grow and flower in most temperate regions where winter temperatures remain above –23C (–10F) (3, 4). Temperatures below –23C (–10F) in the winter and untimely frosts in late winter and spring are two limiting factors in the successful cultivation and flowering of *H. macrophylla*. These conditions result in the death of leaves, stems, or buds. Early fall frosts also damage tissue since *H. macrophylla* often does not acclimate sufficiently early to withstand the freezing temperatures (12). *Hydrangea serrata*, a closely related species from mountainous regions of Japan, is considered more cold hardy than *H. macrophylla* (5, 11). However, no laboratory studies have been conducted to quantify cold hardiness in either species.

Flower buds of both species are generally formed during the fall and over-winter on dormant stems. Flowering occurs from June through August in the southern United States (5). If the terminal flower bud is killed by frosts or low temperatures in the winter, flowering will only occur if lateral flower buds are present and undamaged, or if flowers are produced on the current season's shoots (11, 12). Cultivars most often mentioned as possessing multiple lateral flower buds include *H. macrophylla* 'Dooley', 'Gen. Vicomtesse de Vibraye', 'Mme. Emile Mouillère' and 'Nikko Blue' (4, 5, 11, 15). Flowers of *H. macrophylla* seldom originate from the current season's shoots, but exceptions do exist (4, 11). Haworth-Booth (11) listed 12 remontant flowering cultivars. These cultivars flower regardless of freeze damage as long as new shoots develop during the current season. Cultivars with this characteristic include *H. macrophylla* 'David Ramsey', 'Endless Summer', 'Oak Hill', 'Penny Mac', and 'Decatur Blue' (6, 11, Penny McHenry, personal communication). 'Endless Summer' has survived and flowered reliably for over ten years at Bailey Nurseries, Inc., St. Paul, MN (USDA Hardiness Zone 4) where winter temperatures of –34C (–30F) would kill aboveground stems and buds. 'Endless Summer' has only recently been available for cultivation in the southern United States and, therefore, no information is yet available relative to its ability to survive and flower following untimely frost damage.

Recently, interspecific hybridization between *H. macrophylla*, *H. paniculata* Sieb. and *H. arborescens* L. has been accomplished (13, 17). These latter two species were used to increase cold hardiness and remontant flowering in *H. macrophylla*. Embryo rescue techniques were necessary for recovery of hybrid seedlings (14, 18), and , unfortunately, the plants resulting from these breeding efforts have shown

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limited horticultural merit (19). Identifying *H. macrophylla* cultivars with increased cold hardiness, early acclimation, or late deacclimation would provide breeding lines for intraspecific hybridization, thus avoiding difficulties associated with wide crosses.

The determination of plant cold hardiness by laboratory techniques is well established and is supported by strong relationships between laboratory results and anecdotal field observations in woody plant species (7, 16, 20). Laboratory cold hardiness tests have also been successfully utilized with *Hydrangea quercifolia*, further supporting its usefulness for hydrangeas cold hardiness testing (8). Visual observation of oxidative browning in previously frozen tissues is a reliable indicator of viability (22). Individual plants acclimate differentially and obtain various levels of cold hardiness (23). Plants should be tested at various intervals to determine when acclimation and deacclimation commence and to what degree each individual taxon can resist low temperatures following acclimation (21). The purpose of this study was to identify variation in cold hardiness, acclimation, and deacclimation among nine *H. macrophylla* and one *H. serrata* cultivars. Cultivars in this study were chosen based on putative superior cold tolerance ('All Summer Beauty', 'Mme. Emile Mouillère', 'Nikko Blue', 'Veitchii', and 'Bluebird'), low cold tolerance ('Ayesha', and 'Mariesii Variegata') of stems, or reliable flowering in colder regions or following untimely frosts ('Dooley', 'Endless Summer', 'Générale Vicomtesse de Vibraye') based on anecdotal observations of landscape performance.

Materials and Methods

Container-grown [11.1 liter (#3)] stock plants of nine *H. macrophylla* cultivars ('All Summer Beauty', 'Ayesha', 'Dooley', 'Endless Summer', 'Générale Vicomtesse de Vibraye', 'Mme. Emile Mouillère', 'Mariesii Variegata', 'Nikko Blue', and 'Veitchii') were maintained outdoors under saran shadecloth (45% transmittance), fertilized with 65 g (2.3 oz) slow-release fertilizer (Nutricote 17N–3P–6.7K with micronutrients, Florikan, Sarasota, Fla.)/container twice per year and overhead irrigated. Single-node cuttings from stock plants were rooted in 7.6 × 7.6 × 8.9 cm (3 × 3 × 3.5 in) propagation cells in May 1999. Cuttings were dipped for 5 seconds in 0.1% indole-3-butyric acid-potassium salt (KIBA) and placed in a perlite:peat (3:1 by vol) medium under intermittent mist. After rooting, plants were transferred to a greenhouse bench, fertilized with 7g (0.25 oz) slow-release fertilizer (Nutricote 17N–3P–6.7K with micronutrients)/cell and provided weekly liquid fertilization with 200 mg N/liter (0.33 oz N/gal) (Peters 20N–4.4P–16.6K, Scotts-Sierra Hort. Prod. Co., Marysville, OH).

In November 1999, 45 plants of each *H. macrophylla* cultivar were transplanted three each into fifteen 11.1 liter (#3) containers filled with milled pine bark:sand (6.25:1 by vol) and amended with 0.68 kg (1.5 lb) gypsum per cubic yard. Slow-release fertilizer (Osmocote 24N–1.8P–5.8K, Scotts-Sierra Hort. Prod. Co., Marysville, OH) was incorporated at 4.5 kg (10 lb)/cubic meter (cubic yard) and micronutrients (Micromax, Scotts-Sierra Hort. Prod. Co., Marysville, OH) at 0.91 kg (2 lb)/cubic yard. To control fire ants, 0.91 kg (2 lb) bifenthrin (as Talstar, FMC Corp., Philadelphia, PA)/cubic yard was incorporated. Plants were placed under shade (45% transmittance) on a gravel pad, overhead irrigated, and maintained with standard nursery practices.

All plants were overwintered under the shade structure and provided protection from fall and spring frosts. A supplemental fertilizer application was provided in June 2000 with Nutricote 17–7–8 (17N–3P–6.7K) w/micronutrients at 65g (2.3 oz) per container. Plants of *H. serrata* 'Bluebird' were obtained in November 2000 from a local nursery (McCorkle Nurseries, Dearing, GA). Plants were grown under pine shade in 11.1 liter (#3) containers using the same medium and fertility program as *H. macrophylla* plants.

Hydrangea macrophylla shoots were collected on September 28, November 3, and December 1, 2000, and January 5, February 1, and March 1, 2001. *Hydrangea serrata* stems were collected on December 1, 2000, and January 5, February 1, and March 1, 2001. Leaves, when present, were removed. Twenty uniform 20 cm long (8 in) shoot tips were removed from multiple plants of each taxon, wrapped in moistened paper towels, placed in plastic bags, and transported on ice to Griffin, GA. The terminal 5 cm (2 in) portion was discarded and two 2.5 cm (1 in) long segments were cut from the terminal end of the remaining segment. Freezing studies were accomplished using previously established techniques (7, 8). Two stem sections were wrapped in moistened cheese cloth and placed in one of 18 test tubes (25 × 200 mm) per cultivar. Test tubes were submerged into an ethylene glycol-water solution (1:1) in a precooled temperature bath (Forma Scientific, Model 2425, Marietta, OH) at –2 ± 0.5C (28 ± 1F).

Stem temperature was monitored with thermocouples placed next to samples and recorded by a datalogger (Campbell Scientific, Model CR7, Logan, UT). To insure samples did not undercool, crushed ice was placed in test tubes in contact with the cheesecloth. Samples were held at a constant temperature [–2 ± 0.5C (28 ± 1F)] overnight (approximately 16 hours). Samples were then cooled at a rate not greater than 4C (7F) per hour. Four samples of each cultivar (two test tubes) were removed at 3C (5F) intervals beginning at –3C (27F). The lowest temperature tested was –27C (–17F). Controls to assess the possibility of freeze damage prior to testing were kept at 4C (39F) for the duration of the test.

Samples were allowed to thaw overnight at 4C ± 2C (39F ± 4F). After thawing, samples were removed from test tubes and placed in 100 × 15 mm (3.9 × 0.6 in) disposable petri dishes with water-saturated filter paper to maintain 100 percent humidity. Petri dishes were placed in the dark on their side at room temperature [23 ± 2C (70 ± 4F)] for 10 days. Stems were then visually evaluated for damage as previously described (9, 21, 22). Stems showing discoloration in the cambium or phloem were rated as dead. Control and uninjured stems showed no discoloration or cellular breakdown. The number of stems killed at each temperature was recorded, and the lowest survival temperature (LST) was determined from these data. The LST is the lowest temperature at which little to no damage was observed (20). No statistical analysis was necessary since no within treatment variation existed with only three exceptions. In these three cases, standard deviation is presented. Lack of variation among replicates is expected with only two replicates per temperature, clonal material, and the narrow temperature range [3C (5F)] used (8). Minimum and maximum average air temperatures for the Athens, GA area were provided by the Georgia Automated Environmental Monitoring Network, The University of Georgia, Griffin, GA. (Fig. 1) (10).

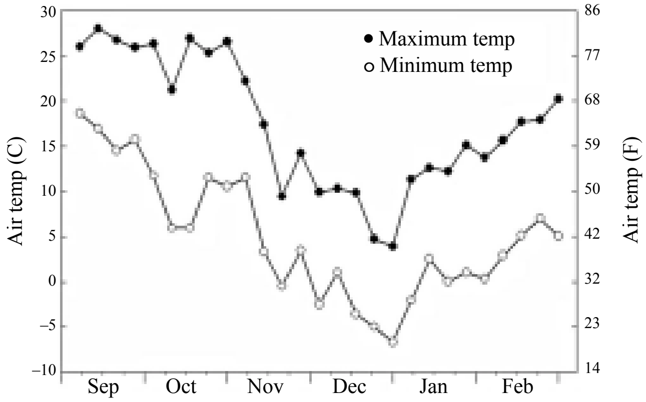

Fig. 1. Minimum and maximum temperatures in Athens, GA, from September 1, 2000, through February 28, 2001.

Freezing damage to a portion of the controls of 'Endless Summer' was observed following the September 30, November 5, and December 1 tests. Thereafter, 'Endless Summer' stems were examined microscopically to insure only undamaged living tissue was used for tests. It was determined that some of the 'Endless Summer' stems which appeared healthy showed oxidative browning of tissues when examined prior to testing. Only stems showing no damage prior to testing were used for subsequent tests. No further variation was observed in 'Endless Summer' and, therefore, variation in earlier data was ignored.

Results and Discussion

The laboratory cold hardiness data presented here is consistent with anecdotal reports of landscape performance of *Hydrangea macrophylla* (5, 12). Published recommendations of the adaptability to USDA hardiness Zone 6 and higher (5, 12, 15) are reasonable based on the results of the cultivars tested. However, hardiness zones are based on average minimum temperatures and do not consider the early or late temperature fluctuations that are so damaging to *H. macrophylla*.

By September 28 all cultivars acclimated to at least –3C (27F) with 'Générale Vicomtesse de Vibraye' reaching –6C (21F). On November 3, 'All Summer Beauty', 'Ayesha', 'Dooley', 'Générale Vicomtesse de Vibraye', 'Mme. Emile Mouillère', and 'Nikko Blue' were cold hardy to –6C (21F). 'Endless Summer', 'Générale Vicomtesse de Vibraye', 'Mariesii Variegata', and 'Veitchii' did not increase in cold hardiness from September 28 to November 3. 'Endless Summer', 'Mariesii Variegata', and 'Veitchii' remained cold hardy to –3C (27F) on November 3. Delayed acclimation could be detrimental in areas where early fall frosts are common, and could result in dead shoots.

Cold hardiness in all cultivars increased by at least 9C (16F) in the period from November 3 to December 1, which included two non-consecutive weeks of freezing temperatures (Fig. 1). A 12C (22F) increase in cold hardiness of 'Veitchii' was evident during this period. Maximum midwinter hardiness occurred on January 5 for all cultivars (Table 1). *Hydrangea macrophylla* 'Dooley', 'Générale Vicomtesse de Vibraye', 'Mme. Emile Mouillère', and *H. serrata* 'Bluebird' were most cold hardy [–24C (–11F)]. 'Endless Summer' was the least cold hardy [–18C (0F)], and was 3 to 6C (6 to 11F) less cold hardy than all other cultivars in the January 5 sampling period.

Deacclimation began in all cultivars by the February 1 collection date. In florists' hydrangea production, bud rest is satisfied by 6 to 8 weeks at 4 to 7C (40 to 45F) (1008 to 1344 chilling hours) (2). Plants in this study received 1053 chilling hours at ≤ 7C (45F) prior to the January 5 collection date (10). According to Bailey (2), light plus temperatures above 10C (50F) promote growth in florists' hydrangea after the chilling requirement is satisfied. Average maximum daily temperatures during January and February 2001 in Athens, GA, were 12C (53F) and 16C (61F), respectively, including 15 days in February with temperatures above 16C (60F) (10). These temperatures were sufficient to trigger shoot expansion and decrease cold hardiness in some cultivars used in this study (Table 1).

Decreases in cold hardiness of 21C (38F) occurred in 'Ayesha' and 'Mariesii Variegata' from January 5 to March 1 with only the controls of each surviving the March 1 test [4C (39F)]. On March 1, 'Dooley', 'Nikko Blue', 'Veitchii', and *H. serrata* 'Bluebird' were most cold hardy [–9C (16F)]. Temperatures below –7 to –4C (20 to 25F) following warm temperatures in late winter kill leaf, stem, and bud tissues of *H. macrophylla* (6, 12). In March 1996 in northeast Geor-

Table 1. Lowest laboratory survival temperature (LST) [C (F)] of nine *Hydrangea macrophylla* (Thunb.) Ser. cultivars and one *Hydrangea serrata* (Thunb. ex J.A. Murr.) Ser. cultivar. Evaluations were made from September 28, 2000, to March 1, 2001, except where noted. LST estimates are treated as constants since no variation among replicates existed in most cases. Standard deviation is given in the three cases where variation did exist.

	Collection dates					
Cultivar	**September 28**	**November 3**	**December 1**	**January 5**	**February 1**	**March 1**
All Summer Beauty	–3 (27)	–6 (21)	–15 (5)	–21 (–6)	–18 (0)	–6 (21)
Ayesha	–3 (27)[z]	–6 (21)	–15 (5)	–21 (–6)	–12 (10)	C[y]
Dooley	–3 (27)	–6 (21)	–15 (5)	–24 (–11)	–18 (0)	–9 (16)
Endless Summer	–3 (27)	–3 (27)	–12 (10)	–18 (0)	–12 (10)	–6 (21)
Générale Vicomtesse de Vibraye	–6 (21)	–6 (21)	–15 (5)	–24 (–11)	–12 (10)	–6 (21)
Mme. Emile Mouillère	–3 (27)	–6 (21)	–15 (5)[z]	–24 (–11)	–12 (10)	–6 (21)
Mariesii Variegata	–3 (27)	–3 (27)	–12 (10)	–21 (–6)	–12 (10)	C[y]
Nikko Blue	–3 (27)	–6 (21)	–15 (5)	–21 (–6)[z]	–12 (10)	–9 (16)
Veitchii	–3 (27)	–3 (27)	–15 (5)	–21 (–6)	–12 (10)	–9 (16)
H. serrata 'Bluebird'	—	—	–15 (5)	–24 (–11)	–15 (5)	–9 (16)

[z]Standard deviation, ±1.5C (±3F).

[y]Only controls survived.

gia, 13 consecutive days with high temperatures of ≤ –2C (28F) occurred including low temperatures of –9C (16F) and –11C (12F) on March 8 and 9, respectively (10). As a result, leaves, stems, and buds of most *H. macrophylla* cultivars were killed with the one reported exception of 'Dooley' which has flowered reliably in Athens, GA, for more than eight consecutive years (6) and *H. macrophylla* 'Penny Mac' (Penny McHenry, personal communication). Based on our observations, flowers of 'Dooley' develop from multiple lateral flower buds in addition to terminal buds, so that if terminal portions of stems are killed flowering occurs from the lateral buds (6).

Exposure to temperatures below freezing are important in establishing cold hardiness, and cultivars acclimate differentially within a given temperature range (23). In our study the first subzero average weekly temperature did not occur until mid-November (Fig. 1). Earlier acclimation would reduce damage to stem tissues and, therefore, potentially increase the number of new shoots and flowers arising in the following season for cultivars that flower primarily on the previous season's growth. For cultivars such as 'Endless Summer', which produces flowers on current season's shoots, cold damage theoretically would not significantly inhibit flowering potential (1).

The most reliable cold hardy cultivars should possess maximum midwinter hardiness, early fall acclimation, and late spring deacclimation. This study indicates that *H. macrophylla* 'Dooley', 'Nikko Blue', 'Veitchii', and *H. serrata* 'Bluebird' may be more adaptable in areas prone to late winter and spring frosts. *Hydrangea macrophylla* 'Ayesha' and 'Mariesii Variegata' deacclimated early and are susceptible to damage from freezing temperatures in late winter or early spring. In fact, 'Mariesii Variegata' is often cited as one of the most frost susceptible (5). Cultivars exhibiting sensitivity to late winter or spring frosts may require protection in spring from freezing temperatures to prevent damage to developing shoots. Although *H. serrata* and *H. macrophylla* developed similar December to February cold hardiness, the inclusion of a single *H. serrata* cultivar, and differences in locations prior to November confound comparative conclusions.

'Dooley', 'Nikko Blue', and 'Veitchii' were the most cold hardy *H. macrophylla* cultivars in this laboratory study. Haworth-Booth (11) and Dirr (6) reported similar results from field trials and observation of landscape performance. However, 'Endless Summer', although the least cold hardy, flowers on new growth and is, therefore, not dependent on flower bud survival from the previous season. Our results and observations indicate that correlations between laboratory cold hardiness and field flowering potential across all cultivars of *H. macrophylla* have exceptions. A progressive approach to breeding superior *H. macrophylla* cultivars would include the use of cold hardy and remontant flowering cultivars.

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