Evaluation of Deciduous Azaleas for Cold Hardiness Potential in the Southeastern United States[1]

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Abstract

Twelve taxa of deciduous azalea were evaluated using laboratory procedures to determine hardiness of stems and flower buds. *Rhododendron atlanticum*, 'My Mary', 'Nacoochee', and 'TNLV1' exhibited the greatest stem cold hardiness, surviving to at least –29C ± 1 (–20F ± 2) in February 1996. *Rhododendron oblongifolium* exhibited the least stem cold hardiness, surviving to only –11C ± 1 (10F ± 2). All results were consistent with previous field studies. Except for *R. viscosum* and *R. serrulatum*, lowest survival temperatures for stems were analogous to reports available in the literature. *Rhododendron viscosum* and 'My Mary' had the lowest survival temperature recorded for flower buds, –23C ± 1 (–9F ± 2), in February 1998 and February 1999, respectively, though not significantly different than most other taxa examined. Lowest survival temperatures for flower buds varied from published accounts, with buds in the present study being less hardy than previously reported. Differences from published reports in the lowest survival temperatures of stems and flower buds are attributed to provenance, temperature fluctuations, cultural effects on the plants, and differences among freeze test protocols.

Index words: cold tolerance, *Rhododendron*.

Species used in this study: Sweet Azalea (*R. arborescens* (Pursh) Torr.); Coastal Azalea (*R. atlanticum* (Ashe) Rehder); Flame Azalea (*R. calendulaceum* (Michx.) Torr.); Piedmont Azalea (*R. canescens* (Michx.) Sweet); Texas Azalea (*R. oblongifolium* (Small) Millais); Hammock Sweet Azalea (*R. serrulatum* (Small) Millais); Pinkshell Azalea (*R. vaseyi* A. Gray); Swamp Azalea (*R. viscosum* (L.) Torr.); 'Buttercup' Azalea; 'My Mary' Azalea; 'Nacoochee' Azalea; and 'TNLV1' Azalea.

Significance to the Nursery Industry

Rhododendrons, as well as many woody plants, are limited in their range of adaptability due more to cold than any other environmental factor. In particular, azaleas are limited by the susceptibility of their flower buds to cold injury. Evaluations of 12 *Rhododendron* taxa for stem and flower bud hardiness in the southeastern United States found *Rhododendron atlanticum*, 'My Mary', and 'Nacoochee' had the greatest stem cold hardiness, surviving to at least –29C ± 1 (–20F ± 2) in February 1996. *Rhododendron oblongifolium* had the least stem cold hardiness, surviving to only –11C ± 1 (10F ± 2). *Rhododendron viscosum* and 'My Mary' had the lowest survival temperature recorded for flower buds, –23C ± 1 (–9F ± 2), in February 1998 and February 1999. Since freeze damage is of major economic importance even in subtropical regions, the information provided is useful to growers concerned about the cold adaptation of deciduous azaleas and to hybridizers for selection of cold hardy parental germplasm.

[1]Received for publication May 30, 2000; in revised form September 18, 2000.

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Introduction

Showy floral displays have increased the popularity of deciduous azaleas in the southeastern United States (2). Seedling variations, introgression and interspecific crosses, and environmental influences have produced a vast array of natives and hybrids available in pastel colors and unusual forms (8). However, breeders and growers have concerns regarding the adaptation of deciduous azaleas to freezing stress because cold, more than any other environmental factor, limits the northern distribution range of woody plants (6). The universal problem of freeze damage is of major economic importance even in subtropical regions (20). Azalea flower buds are the most vulnerable organ to cold injury and are particularly susceptible to hardening and dehardening induced by temperature fluctuations (1, 10, 11, 16). This phenomenon is quite common in southern geographic regions even during midwinter. Many *Rhododendrons* have extended north-south ranges, and provenance can dictate the maximum low temperature survival (7, 9, 14). Though hardiness ratings are available for most species and cultivars, these ratings are based on field observations in a few locations and may not be applicable to different geographic regions (15). Studies conducted by Lindstrom and Dirr (14) have indicated a strong correlation between cold hardiness observed in the field and laboratory tests when plants were evaluated on multiple dates. The objective of this study was to evaluate 12 taxa of *Rhododendron* for stem and flower bud hardiness in the southeastern United States.

Materials and Methods

Twelve taxa of deciduous azalea (Table 1) obtained from commercial sources were evaluated for stem and flower bud cold hardiness. The taxa evaluated were *R. arborescens* (Pursh) Torr., *R. atlanticum* (Ashe) Rehder, *R. calendulaceum* (Michx.) Torr., *R. canescens* (Michx.) Sweet, *R. vaseyi* A. Gray, three genotypes of *R. viscosum* (L.) Torr., 'Buttercup', 'My Mary', 'Nacoochee', and 'TNLV1'. Two *R. viscosum* genotypes were formerly classified as *R. serrulatum* (Small) Millais and *R. oblongifolium* (Small) Millais, and here will be referred to as *R. serrulatum* and *R. oblongifolium*, respectively. 'Buttercup' is a Knap Hill hybrid, 'My Mary' is a species hybrid with *R. atlanticum*, *R. austrinum* (Small) Rehder, and *R. periclymenoides* (Michx.) Shinners in the parentage, 'Nacoochee' is an interspecific hybrid between *R. atlanticum* and *R. periclymenoides*, and 'TNLV1' is a hybrid with *R. molle* (Blume) G. Don subsp. *japonicum* (A. Gray) K. Kron parentage. All of the above taxa, except *R. arborescens* and *R. calendulaceum*, were evaluated for stem hardiness. All taxa were evaluated for flower bud hardiness except *R. oblongifolium*, *R. vaseyi*, and 'Buttercup'. *Rhododendron oblongifolium* was removed from the study prior to Winter 1996–1997 due to death of plants the previous winter, and *Rhododendron vaseyi* lacked sufficient flower buds for evaluation. 'Buttercup' was eliminated from the study due to unseasonably warm temperatures in late November and early December in both test years that resulted in premature flower opening.

Each representative of the 12 taxa, except specimens of *R. calendulaceum*, was clonally propagated and grown in a #1 (3.8 liter) container. Representatives of *R. calendulaceum* were seedlings and were grown in #7 (26.5 liter) containers. Twelve plants of *R. atlanticum*, *R. canescens*, *R. serrulatum*, *R. viscosum*, 'Buttercup', 'My Mary', 'Nacoochee', and 'TNLV1' were planted into a field in Griffin, GA, in a randomized complete block design in mid-November, 1994. *Rhododendron oblongifolium* and *R. vaseyi* were added to the plot in August 1995, and *R. arborescens* and *R. calendulaceum* were added to the plot in April 1997. Death of *R. canescens* plants required replacement of one-half of the plants in August 1995. The research plot was located under a canopy of mixed deciduous trees, drip irrigated as needed, and fertilized twice per year with Azalea, Camellia, Rhododendron Food 16N–$2P_2O_5$–$3K_2O$ (The Scotts Company, Marysville, OH) at a rate of 1/3 cup (37g) per plant.

As described by Lindstrom and Dirr (14), 36 uniform stem tips, each 10 cm (4 in) in length, were collected from each taxon on December 16, 1995, February 3, 1996, December 7, 1996, and February 8, 1997, and prepared for testing within two hours of collecting. On December 6, 1997, February 7, 1998, December 5, 1998, and February 6, 1999, 30 flower buds of each taxon were collected and prepared for freezing. To prepare the stems and buds for freezing, the terminal 7 cm (2.8 in) were removed, wrapped in cheesecloth and placed in a 25 × 200 mm test tube (1 × 8 in). Leaves, if present, were removed from the stems. Tubes were then submerged in ethylene glycol-water solution (1:1) in a Forma Scientific Model 2425 temperature bath (Forma Scientific, Marietta, OH) precooled to –2C ± 0.5 (28F ± 1).

Stem and bud temperatures were measured by thermocouplers placed next to the samples and recorded by a Campbell Scientific datalogger (Model CR7-X, Campbell Scientific, Inc., Logan, UT). Crushed ice crystals were applied to the wet cheesecloth of stem samples to insure that the samples did not undercool. Temperature of the samples was held constant at –2C ± 0.5 (28F ± 1) for approximately 14 hrs. Samples were then cooled at a rate of not greater than 4C (7F) per hour. Four stems and three flower buds of each taxon were removed from the bath at progressively lower 3C (5F) temperature intervals. Controls were prepared and kept at 4C (39F) for the duration of the freezing test.

Frozen samples were allowed to thaw overnight at 4C ± 2 (39F ± 4). Samples were then removed from the tubes and placed in disposable, round, 100 × 15 (3.9 × 0.6 in) petri dishes containing filter paper saturated with distilled water to maintain 100 percent relative humidity. The petri dishes were placed on their sides in the dark at 22C ± 2 (72F ± 4) for 10–14 days when samples were visually evaluated for injury. Stems showing brown discoloration and breakdown of cells in the cambium and phloem were rated as dead. Browning was observed with the naked eye and with the aid of a Wild Heerbrugg M5A stereomicroscope (Wild Heerbrugg Ltd., Heerbrugg, Switzerland) when needed. Controls and samples not injured in the freezing tests were identified by green coloration and no discoloration or breakdown. Flower buds were dissected and the number of dead (black) and live (white) florets were counted. A bud was rated as alive if >50% of the florets were alive. The number of stems and flower buds killed at each temperature was recorded and from this data the lowest survival temperatures (LSTs) were determined for each species. The LST is the lowest test temperature at which survival was observed (14). In many cases, no variability was observed among replicates when determining the LST. Where variability was present, the standard error was reported. The sensitivity of the laboratory evaluation detected only cold hardiness differences greater than 3C (5F). The

Table 1. **Lowest survival temperatures (LST C ± SE) for stems and buds of 12 *Rhododendron* taxa.**

	Date							
	12–16–95	02–02–96	12–07–96	02–08–97	12–06–97	02–07–98	12–05–98	02–06–99
Taxa	Stems	Stems	Stems	Stems	Buds	Buds	Buds	Buds
R. arborescens	—	—	—	—	–17 ± 1	–16 ± 1	–18	–20 ± 1
R. atlanticum	–27[y]	–29 ± 1	–27[y]	–27[y]	–22 ± 1	–22 ± 1	–21	–22 ± 1
R. calendulaceum	—	—	—	—	–19 ± 1	–18	–20 ± 1	–22 ± 1
R. canescens	–19 ± 1	–26 ± 1	–24	–25 ± 1	–18	—	–21	–21
R. oblongifolium[z]	–11 ± 1	–10 ± 1	—	—	—	—	—	—
R. serrulatum	–15	–25 ± 1	–17 ± 1	–20 ± 1	–13 ± 1	–20 ± 1	–16 ± 1	–21
R. vaseyi	–26 ± 1	–20 ± 1	–25 ± 1	–27[y]	—	—	—	—
R. viscosum	–17 ± 1	–20 ± 1	–20 ± 1	–20 ± 1	–22 ± 1	–23 ± 1	–21	–20 ± 1
'Buttercup'	–18	–22 ± 1	–14 ± 1	–27[y]	—	—	—	—
'My Mary'	–23 ± 1	–30[y]	–27[y]	–27[y]	–19 ± 1	–22 ± 1	–19 ± 1	–23 ± 1
'Nacoochee'	–24	–29 ± 1	–23 ± 1	–26 ± 1	–18	–21	–19 ± 1	–20 ± 1
'TNLV1'	–23 ± 1	–30[y]	–26 ± 1	–27[y]	–20 ± 1	–21	–20 ± 1	–21

[z]Removed from the study due to death of plants the winter of 1995–1996.

[y]Lower limit of freeze test on the given date; all replications survived this exposure.

lower limits of the freeze bath were –27C (–17F) in December 1995, December 1996, February 1997 and –30C (–22F) in February 1996.

Results and Discussion

Stem hardiness. *Rhododendron* taxa varied widely in stem hardiness (Table 1). *Rhododendron atlanticum*, 'My Mary', 'Nacoochee', and 'TNLV1' exhibited the greatest cold hardiness, surviving to at least –29C ± 1 (–20F ± 2) in February 1996. All four taxa were consistent between sampling dates in the first and second test year. *Rhododendron atlanticum* was the most consistent taxon both within and between years, achieving at least –27C (–17F) on all four test dates. It is interesting to note that 'My Mary' and 'Nacoochee' have *R. atlanticum* in their parentage. Furthermore, 'TNLV1' contains *R. molle* subsp. *japonicum* in its parentage, a species that Sakai et al.(17) reported hardy to –50C (–58F). *Rhododendron oblongifolium* exhibited the least cold hardiness, surviving to only –11C ± 1 (10F ± 2). All taxa, except *R. oblongifolium* and *R. vaseyi*, were hardier in February than December in Winter 1995–1996. Since *R. oblongifolium* and *R. vaseyi* were added to the field plot in August 1995, transplant date may account for the discrepancy. Lindstrom (13) reported similar results in Leyland Cypress [x *Cupressocyparis leylandii* (A.B. Jacks and Dallim.) Dallim. and A.B. Jacks] following a study to determine the influence of transplant date on cold hardiness. Plants of Leyland Cypress transplanted into the field in August 1989 were 3C (5F) less hardy in February 1990 than in December 1989.

Stem hardiness of *R. canescens* increased 7C ± 1 (12F ± 2) between December 1995 and February 1996, but the following season no significant difference in hardiness occurred between December [–24C (–11F)] and February [–25C ± 1 (–13F ± 2)]. In August 1995, one-half of the plants from which *R. canescens* stem samples were randomly collected were replaced in the field plot because of unexplained plant death. Due to the transplant date, plants of *R. canescens* may not have had adequate time to acclimate or may have acclimated at a different rate prior to the December 1995 test date, resulting in an underestimate of the LST. 'Buttercup' exhibited a similar pattern of cold hardiness in the second year of study. The stem hardiness of established plants increased only 4C ± 1 (7F ± 2) between December and February in year one, but stem hardiness increased 13C ± 1 (22F ± 2) in year two. The increase in year two is attributed to a lack of cold hardiness in December as supported by sporadic flowering in late November and early December 1996.

Stem hardiness was similar (± 3C) to published field observations for all taxa except *R. viscosum* and *R. serrulatum* (3, 5, 8). *Rhododendron viscosum* has been reported to be hardy to–40C (–40F) (17) while *R. serrulatum* is reported to be hardy only to –15C (5F) (5). However, after two years of investigation, the maximum stem hardiness achieved by *R. viscosum* was –20C ± 1 (–4F ± 2), while *R. serrulatum* exhibited a maximum stem hardiness of –25C ± 1 (–13F ± 2). One possible explanation is that in recent years several taxonomists have lumped *R. viscosum* and *R. serrulatum* into a single species, *R. viscosum*, due to an absence of distinguishable morphological characteristics (12). *Rhododendron serrulatum* had been previously recognized as a distinct southern taxon with a distribution extending from middle Georgia to central Florida, and westward to the coast of southeast Louisiana (4, 18, 21). *Rhododendron viscosum* has an extremely wide distribution that partially overlaps the distribution of *R. serrulatum*. Its distribution extends from Maine, Massachusetts, and Connecticut to North Carolina and southeastern South Carolina, and west to Ohio, southeastern Tennessee, and Louisiana (4). Woody plant species having wide geographic ranges would likely have wide differences in cold hardiness. Plants from warm provenances often have been found to be less cold hardy at specific times in early winter because they acclimate more slowly or later than accessions from colder origins (7). Flint (7) found considerable variation in twig hardiness among 38 ecotypes of *Quercus rubra*. Estimated extreme minimum temperatures ranged from –23C (–9C) for accessions collected in Union County, GA, to –46C (–51F) for accessions from Cass County, MN. Similar variations have been observed in *Cornus stolonifera* (19). Hence, it seems quite plausible that the two genotypes of *R. viscosum* in our investigation are ecotypes that are intermediate in hardiness to those previously evaluated. *Rhododendron oblongifolium* has also been lumped under the species heading *R. viscosum*; however, its maximum hardiness agrees with previously published reports (5, 12). The distribution of *R. oblongifolium* extends from northern Texas through eastern Oklahoma and into Arkansas (4, 12). Procedural differences offer a second explanation for the difference in hardiness of *R. viscosum* in the present study and the hardiness determined by Sakai et al. Following collection, Sakai et al. (17) acclimated the stems and flower buds to their maximum level by exposing the samples to artificial hardening.

Flower bud hardiness. Flower bud hardiness remained equal or increased between sampling dates in both test years. *Rhododendron serrulatum* was the least hardy taxon in December of both test years with LSTs of –13C ± 1 (9F ± 2) and –16C ± 1 (3F ± 2) in 1997 and 1998, respectively. It was significantly different from all other taxa except *R. arborescens* in December 1997, but in December 1998, *R. serrulatum* was only significantly different from *R. atlanticum*, *R. canescens* and *R. viscosum*. Furthermore, *R. serrulatum* had the greatest increase in hardiness between December and February in both years. The LSTs increased 7C ± 1 (12F ± 2) in year one and 5C ± 1 (9F ± 2) in year two. The lowest survival temperature, –23C ± 1 (–9F ± 2), was recorded for *R. viscosum* in February 1998 and 'My Mary' in February 1999. *Rhododendron arborescens* and *R. calendulaceum* were the least hardy taxa in February 1998, surviving to –13C ± 1 (9F ± 2) and –16C ± 1 (3F ± 2), respectively, and they were the only taxa significantly different from *R. viscosum* in February 1998. No significant differences in hardiness were found among taxa in February 1999 with hardiness values ranging from –20C ± 1 (–4F ± 2) to –23C ± 1 (–9F ± 2).

In a previous study, Pellett et al. (16) examined the cold hardiness of various provenances of *R. calendulaceum* and *R. viscosum*. The cold hardiness of the flower buds of *R. calendulaceum* and *R. viscosum* ranged from –20C (–4F) to –25C (–13F) and –30C (–22F) to –35C (–33F), respectively. Plants of *R. calendulaceum* and *R. viscosum* were grown in Vermont from seeds collected in Kerens, WV, and Packardville, MA, respectively. Seeds of both species were also collected along the Blue Ridge Parkway in North Carolina and grown in Vermont. No clear relationship was found between the effects of elevation and latitude on cold acclimation. Sakai et al. (17) reported flower buds of *R. arborescens* and *R. viscosum* grown in Sapporo, Japan, to be hardy to –30C (–22F). Pellett and Moe (15) reported the midwinter flower bud hardiness of *R. arborescens* plants grown in Hopkinton, MA, to be –24C (–11F). In the present study, the lowest survival temperatures for the flower buds of *R. arborescens*, *R. calendulaceum* and *R. viscosum* ranged from –16C ± 1 (3F ± 2) to –20C ± 1 (–4F ± 2), –18C (10F) to –22C ± 1 (–8F ± 2), and –20C ± 1 (–4F ± 2) to –23C ± 1 (–9F ± 2), respectively. The accessions examined in this study were grown from an unknown seed source by a commercial nursery in Georgia. Reported differences in the lowest survival temperatures of flower buds are attributed to genotypic differences, genotype × environment interactions (e.g. provenance, temperature fluctuation, cultural practices) and/or freeze test protocols. Both Sakai et al. (17) and Pellett and Moe (15) utilized a preconditioning treatment of artificial hardening to maximize hardiness. While differences were found in the lowest survival temperatures of the flower buds, *R. calendulaceum* and *R. viscosum* ranked in the same order of cold hardiness. The ranking of *R. arborescens* may be attributed to preconditioning procedures, genotype × environment interactions and/or genotypic differences.

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